

PB84-171701

Changes in Terrestrial Ecology Related to a
Coal-Fired Power Plant
Wisconsin Power Plant Impact Study

Wisconsin Univ.-Madison

Prepared for

Environmental Research Lab.-Duluth, MN

Mar 84



U.S. Department of Commerce
National Technical Information Service

NTIS

EPA-600/3-84-051
March 1984

FB84-17 170 1

CHANGES IN TERRESTRIAL ECOLOGY RELATED
TO A COAL-FIRED POWER PLANT

Wisconsin Power Plant Impact Study

by

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This study was conducted in cooperation with

Water Resources Center
Wisconsin Power and Light Company,
Madison Gas and Electric Company,
Wisconsin Public Service Corporation,
and Wisconsin Department of Natural Resources

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U.S. ENVIRONMENTAL PROTECTION AGENCY
DULUTH, MINNESOTA 55804

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TECHNICAL REPORT DATA (Please read instructions on the reverse before completing)		
1. REPORT NO. EPA-600/3-84-051	2.	3. RECIPIENT'S ACCESSION NO. P80 4 17170 1
4. TITLE AND SUBTITLE Changes in Terrestrial Ecology Related to a Coal-Fired Power Plant	5. REPORT DATE March 1984	
	6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S) D.E. Willard, W.W. Jones, and J. Benforado	8. PERFORMING ORGANIZATION REPORT NO.	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Institute for Environmental Studies University of Wisconsin-Madison Madison, Wisconsin 53706	10. PROGRAM ELEMENT NO.	
	11. CONTRACT GRANT NO. R80-3971	
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Research Laboratory 6201 Congdon Blvd. U.S. Environmental Protection Agency Duluth, Minnesota 55804	13. TYPE OF REPORT AND PERIOD COVERED EPA-ORD	
	14. SPONSORING AGENCY CODE EPA/600/03	
15. SUPPLEMENTARY NOTES		
16. ABSTRACT This report summarizes the effects of a coal-fired power plant on terrestrial plants and animals. Research was conducted from 1971 through 1977 at the Columbia Generating Station in the eastern flood-plain of the Wisconsin River in south-central Wisconsin. Initial studies were largely descriptive, involving development of species lists and documentation of habitats. Mapping plant communities documented extensive changes, most notably heavy losses of sedge meadow habitats and increases in open water. Impacts on plant communities caused concomitant changes in animal communities. Bird populations were analyzed through observations in a sampling system consisting of five permanent transects, each having 17 or 18 stations and representing the entire range of plant communities. Observations of a nesting colony of great blue herons showed that the nesting population decreased and foraging habits changed as a result of the impact of the cooling lake on the wetlands. Drift fence-pitfall trapping was used to obtain information on presence and abundance of species, migration routes and seasonal use of different habitats, and occurrence of rare and endangered species. The effects of drift fence construction and orientation, trap dimensions, cycles in time, and weather variables on the results obtained by drift fence-pitfall trapping are discussed in this report.		
17. KEY WORDS AND DOCUMENT ANALYSIS		
a. DESCRIPTORS	b. IDENTIFIERS OPEN ENDED TERMS	c. COSATI Field/Group
18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 111
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

NOTICE

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FOREWORD

The U.S. Environmental Protection Agency (EPA) was designed to coordinate our country's efforts toward protecting and improving the environment. This extremely complex task requires continuous research in a multitude of scientific and technical areas. Such research is necessary to monitor changes in the environment, to discover relationships within that environment, to determine health standards, and to eliminate potentially hazardous effects.

One project, which the EPA is supporting through its Environmental Research Laboratory in Duluth, Minnesota, is the study "The Impacts of Coal-Fired Power Plants on the Environment." This interdisciplinary study, centered mainly around the Columbia Generating Station near Portage, Wis., involves investigators and experiments from many academic departments at the University of Wisconsin and is being carried out by the Environmental Monitoring and Data Acquisition Group of the Institute for Environmental Studies at the University of Wisconsin-Madison. Several utilities and State agencies are cooperating in the study: Wisconsin Power and Light Company, Madison Gas and Electric Company, Wisconsin Public Service Corporation, Wisconsin Public Service Commission, and Wisconsin Department of Natural Resources.

This report summarizes the effects of a 1054-MW coal-fired power plant on terrestrial plants and animals. Research was conducted from 1971 through 1977 at the site of the Columbia Generating Station. Initial studies were largely descriptive, involving development of species lists and documentation of habitats. Mapping of plant communities documented extensive changes, most notably heavy losses of sedge meadow habitats and increases in open water. Impacts on plant communities brought about concomitant changes in animal communities.

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ABSTRACT

This report summarizes the effects of a 1054-MW coal-fired power plant on terrestrial plants and animals. Research was conducted from 1971 through 1977 at the site of the Columbia Generating Station in the eastern floodplain of the Wisconsin River in south central Wisconsin.

Initial studies were largely descriptive, involving development of species lists and documentation of habitats. Mapping of plant communities documented extensive changes, most notably heavy losses of sedge meadow habitats and increases in open water. Impacts on plant communities brought about concomitant changes in animal communities.

Bird populations were analyzed through observations in a sampling system consisting of five permanent transects, each having 17 or 18 stations and representing the entire range of plant communities. In mean analysis, a t-test was applied to identify significant differences in the mean number of birds observed in each station during each year of study. The Shannon-Weaver function, which combines species richness and evenness components into a single index, was used as a measure of diversity. Polar ordination, a type of multivariate analysis based on a similarity coefficient to measure "distances" between stations, revealed many changes in the composition and structure of bird communities. Observations of a nesting colony of great blue herons showed that the nesting population decreased and foraging habits changed as a result of the impact of the cooling lake on the wetlands.

Drift fence-pitfall trapping is one source of information on presence and abundance of species, migration routes and seasonal use of different habitats, and occurrence of rare and endangered species. This report summarizes the effects of drift fence construction and orientation, trap dimensions, cycles in time, and weather variables on the results obtained by drift fence-pitfall trapping.

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ACKNOWLEDGMENTS

The authors wish to express their sincere appreciation to the following University of Wisconsin students and staff who seasonally braved hordes of mosquitoes and sub-zero temperatures in contributing countless early morning hours of their time to carry out the investigations described in this report: Randy Ballweg, Gloria Boone, Steve Brick, Jeff Burns, Pam Burt, Doug DeMaster, Dennis Grossman, Lois Harter, Michael John Jaeger, John Medelson, Ellen McMahon, Sharon Mikol, Susan Rodewald, Don Samuelson, Jerry Schwartzmeier, Rod Smith, George Splawn, and Susan Stackler.

We are grateful for the assistance of Dr. Edward B. Beals in conducting and analyzing the polar ordinations of bird transect data. Steve Horn prepared several of the figures used in this report.

SECTION 1

INTRODUCTION

This report summarizes the evolution and interrelationships between the terrestrial plant and animal studies that took place on the Columbia Generating Station Site from December 1970 until August 1977. It contains final reports from the early descriptive work conducted by a number of researchers, the bird transect and great blue heron studies of W. W. Jones and the small vertebrates study of Jay Benforado. It connects the wetland vegetation report of Bedford (1982) and the wetland passerine bird study of Jaeger (1980). By design many of the studies reported elsewhere in this series originated from questions raised by the early descriptive work. Of interest are the closely related groundwater studies by Andrews and Anderson (1980) and the remote sensing work by Wynn and Kiefer (1983).

DESCRIPTION OF THE COLUMBIA GENERATING STATION SITE

From 1971 to 1977, three utility companies, the Wisconsin Power and Light Company, the Madison Gas and Electric Company, and the Wisconsin Public Service Corporation constructed two 527,000-kilowatt coal-fired electrical generating stations on the Columbia Energy Center site in south-central Wisconsin. The site is located on the eastern floodplain of the Wisconsin River 4 miles south of the city of Portage, Wisconsin, in the west central portion of Columbia County. It is bounded on the south by county road JV and on the west by the Wisconsin River, though some additional acreage exists across the river from the town of Dekorra. The Chicago, Milwaukee and St. Paul Railroad constitutes the east boundary from JV north until it intersects U.S. Highway 51. At that point the highway becomes the boundary. The site extends north to the Portage city limits (Figure 1).

The construction site proper consists of approximately 1,110 ha of land. It is joined to an additional 800 ha owned by the Wisconsin Power and Light Company, making a total of 1,900 ha (4,700 acres). The facility includes a cooling lake of approximately 200 ha along the southeastern boundary, a coal storage area and main generating site of approximately 100 ha at the eastern middle of the site, and a 28 ha ash disposal pit at the northern edge of the site (Figure 2). An approximate value for total area impacted directly by the construction is 405 ha.

Topographically, 75% of the site is wetland floodplain with four drier hills in the southern portion. The dominant vegetation is sedge meadow and

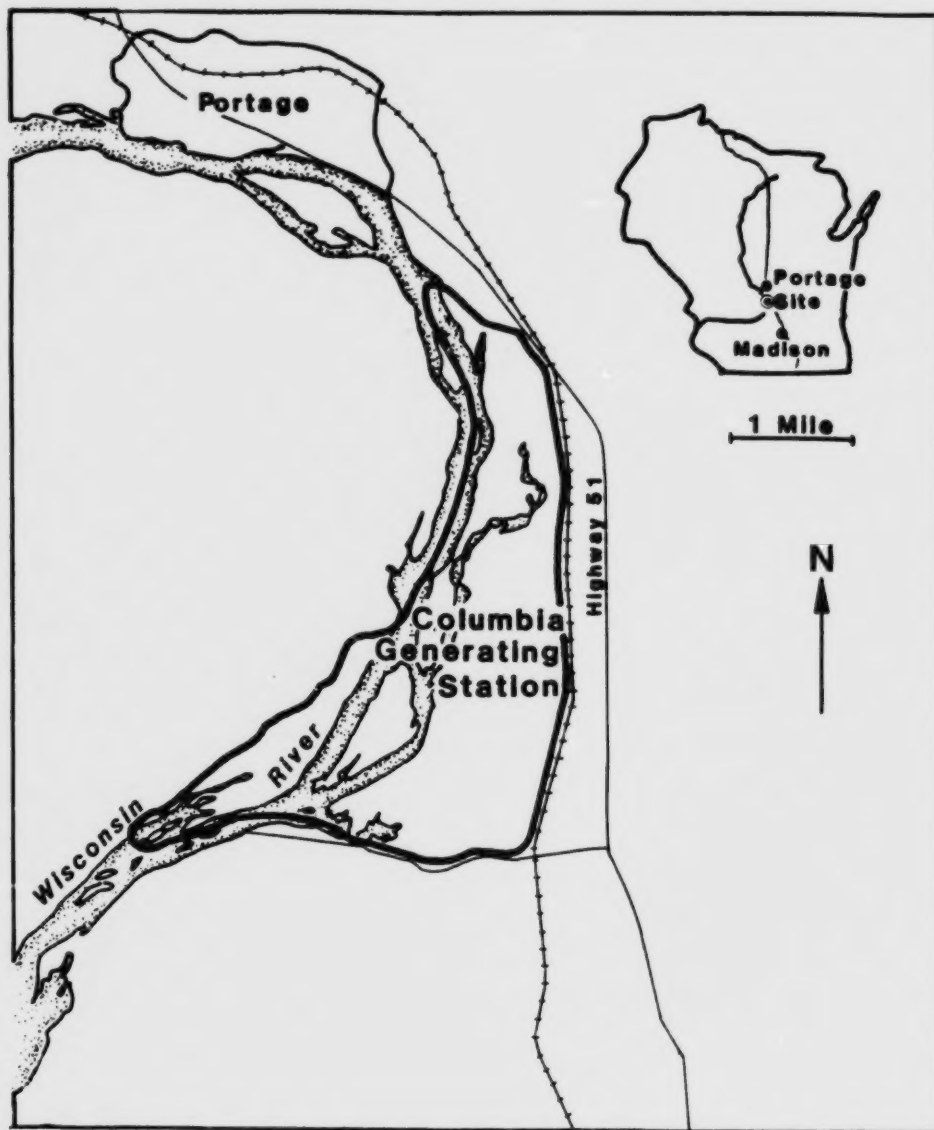


Figure 1. The location of the study area.

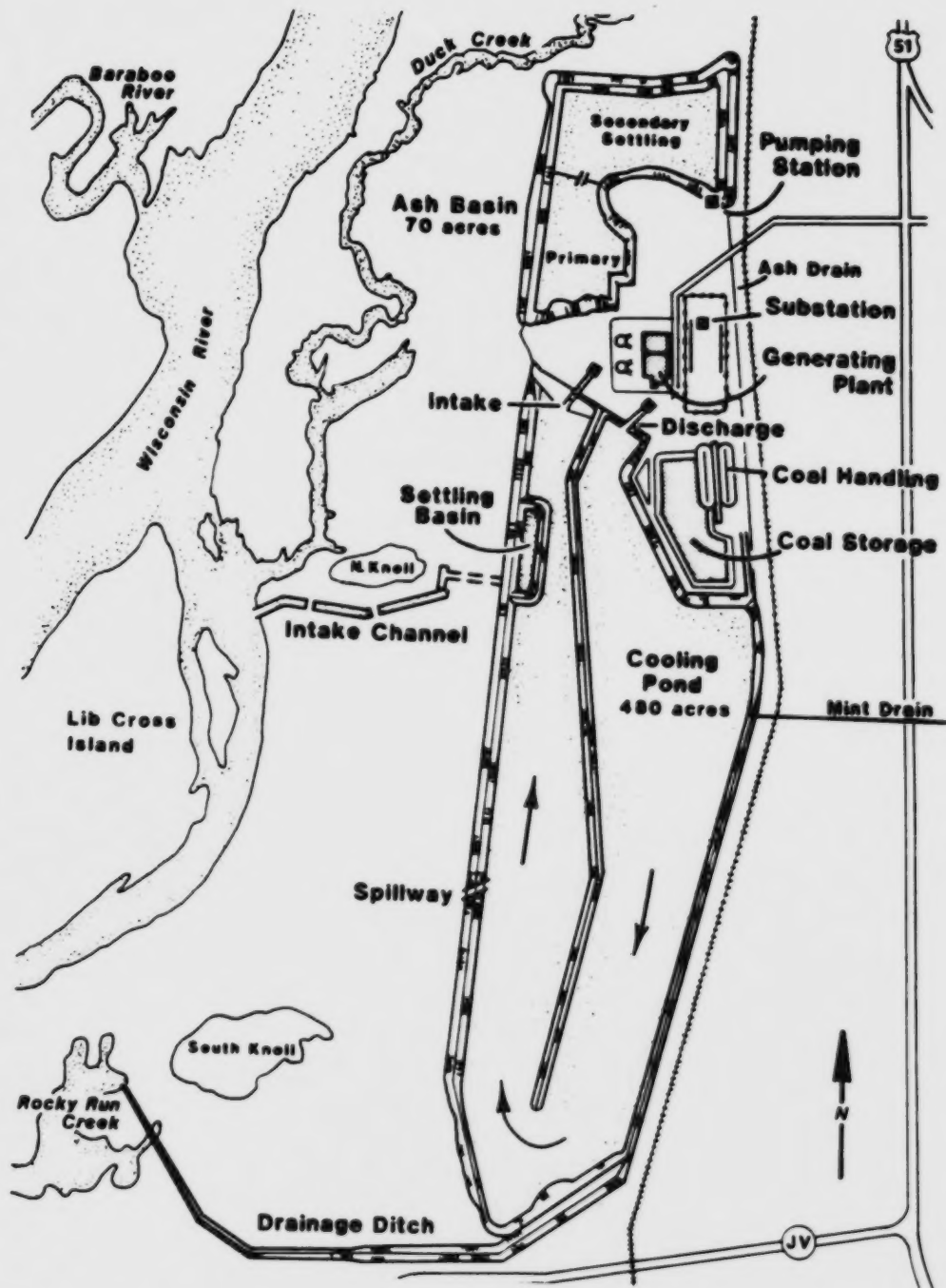


Figure 2. Major features at the Columbia Generating Station Site.

lowland forest. The indirect effects and the effects remote from the site--including air pollution and power lines--cover a far greater area.

BACKGROUND

The focus and intensity of ecological studies at the Columbia Generating Station evolved over time from a low-budget, 1-yr study funded by the three utilities in 1971, to a large, multi-year study supported additionally by the U.S. Environmental Protection Agency (U.S. EPA) beginning in 1975. A brief discussion of this evolution is presented to provide the proper framework for evaluating the study.

The Columbia Generating Station began in controversy for two reasons. The facility itself had difficulty with its initial industrial and floodplain zoning permits and variances and the passage of the National Environmental Policy Act (NEPA) on January 1, 1970 and the rapid response of the State of Wisconsin in passing its own bill (WEPA) caused considerable confusion. State and local environmental groups were again becoming active. They contended that the construction of Columbia I (the first of the 527 MW units) required an environmental impact statement. The utilities claimed otherwise, continuing a series of controversies. In retrospect, it appears the utilities commissioned the study for three reasons:

1. The passage of NEPA and WEPA foreshadowed the need for information about the environmental impacts of generating stations.
2. A variety of permitting problems depended on ecological information.
3. Public relations might be improved by funding an ecological study by an outside unbiased group.

As time wore on, these goals changed to a desire for some stable targets for design criteria and permit standards. This later need was reinforced as the governmental regulatory agency began searching for standards of quality assurance and environmental protection.

The research at Columbia required considerable cooperation between the Wisconsin Department of Natural Resources (WDNR) and later the Wisconsin Public Service Commission. The U.S. Army Corps of Engineers showed interest in the intake channel. The WDNR had the task of considering the wide variety of permits required under existing law as well as developing some criteria for writing environmental impact statements under WEPA. Neither the WDNR, the utilities, nor the Columbia Project study group understood the ramifications of this law (WEPA) and this development was the first case.

CONCEPTUAL FRAMEWORK

The primary objective of the Columbia study was to document the environmental changes caused by the Columbia Generating Station. A number of philosophical notions were accepted in beginning this study:

1. Environmental Impact Statements largely had been predictions. While it could be observed that things were different around existing power plants, it was not known "what it was different from." Thus, the usefulness of impact statements suffers. The documentation at the Columbia Site should help correct this weakness.
2. It was recognized that correlation is not causality and thus actual physical links between correlated events were sought. Considerable effort was devoted to proving these causal relationships.
3. The environment of any object is the continuous interaction of a complex number of forces, conditions and other objects. This project concentrates on a series of what are felt to be critical environmental components. The choice of components depends on three criteria:
 - a. Whether the component was predicted to change;
 - b. whether the change was judged significant, and
 - c. whether the present state of knowledge and equipment could adequately measure the change.

As a general notion the ecological concept was accepted *a priori* that everything is interrelated. Thus, given a perturbation as great as the construction of the Columbia Generating Station, all systems should change, some more than others. Furthermore, it was accepted that some systems would have greater impact on the quality of human life in the immediate future (<20 years) than would others. As a final consideration it was felt that a need existed to balance the expense of some methods of evaluation against the significance and relevancy of the evaluations.

APPROACH

The purposes of the on-site research expanded to meet the needs of the participants. They also responded to the broadening conceptual framework of the researchers as the work evolved through five organizational phases.

1. Descriptive phase. This was primarily fieldwork developing species lists, evaluating habitat and documenting the elements of the natural history of the important species.
2. Population phase. Field censuses were made on a regular basis, using traps and nets to assess population densities.

3. Community level phase. Plant communities and habitat types were mapped and analyzed using aerial photography, point quarter and transect methods.
4. Ecosystem level studies. The hydrogeological studies were limited to changes in plant communities as observed in aerial photographs (Wynn and Kiefer 1983).
5. Analytic studies of physiological and behavioral responses to impact. On site, these studies dealt with nutrient storage and use in wetland plants (Bedford 1983) and changes in avian breeding and foraging behavior. (Jaeger 1980 and this report.)

This approach was taken to aid in balancing the values of long-term qualitative observations versus short-term quantitative studies. Obviously, with a site as large and diverse as Columbia, it was impossible to document all potential ecological impacts. The descriptive Phase I work aided in making some of the choices outlined in the previous section. Since the wetlands and dry knolls were expected to be affected by construction activities, they were among the first areas studied. Many of the larger animals (white-tailed deer, red fox) left the site following the initiation of construction and there were few left to study. Reptiles and amphibians were not judged important by the funding agencies or the public, thus there was little support to carry on with studies of them. Furbearers were important locally to trappers but again, because of abundant habitat nearby, were not judged worthy enough to study.

Such decisions were not made at the onset of the project, but were developed as descriptive studies proceeded and more of the study area and the utilities' plans were learned. The upshot of this selection process was that wetland vegetation and vegetation susceptible to coal burning emissions (SO_2 primarily) were studied. Fish and other aquatic resources were studied because of changes expected in aquatic and semi-aquatic habitats. Birds and to a lesser extent small mammals were selected for study because of population abundance, ease of study, and use as indicators of change.

As mentioned previously, wetland vegetation studies have been reported elsewhere in Bedford (1983) and Wynn and Kiefer (1983). Forestry work and herbaceous plant studies are reported in Tibbitts et al. (1982). Jaeger's (1980) study of wetland passerines is also published in a separate volume and studies of fish and other aquatic resources are reported in Magnuson et al. (1980a,b).

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Plant Communities

The construction of the Columbia Generating Station resulted in the net loss of 638 ha of native plant communities on the 2046 ha site. The largest single loss was in sedge meadow (481 ha). Four minor communities (alder thicket, fen, northern wet forest, and northern wet mesic forest) were lost completely. Seepage and upwelling of cooling lake water under the dikes is dislodging peat mats which continues to affect the sedge meadow community west of the cooling lake.

Mammals

White-tailed deer populations on the site declined with the onset of construction due to increased hunting pressure. Habitat destruction and plant facilities, which tend to restrict deer movements along the Wisconsin River, have continued to keep deer populations depressed. Increases in the amount and depth of water in the sedge meadow should favor muskrats but may limit the range of voles and shrews.

Drift fence-pitall trapping proved a suitable method for capturing a variety of small mammals, reptiles, and amphibians. Capture rates depend on trap size and shape, orientation, timing, and weather conditions. The method was useful for gathering baseline data.

Birds

Construction activities directly affected bird abundance, however, if the habitat destruction was modest, abundance levels in the affected areas returned to pre-disturbance levels with the completion of the construction activity. In the sedge meadow and old field communities, construction activities kept species abundance below pre-construction levels.

Species diversity indices generally decreased over time in those sampling stations impacted by construction activities. This suggests that construction activities had a larger community level impact than species abundance changes alone indicated.

The disturbances on the site seemed to favor the more common bird species over the rarer ones. Species which declined in number during the study period include harriers, sandhill cranes, and great blue herons. A great blue heron colony which used the Columbia sedge meadow for feeding declined from 113 active nests in 1974 to 16 nests in 1977.

Polar ordination was useful in considering how certain environmental parameters affect bird species distributions. The results suggest that polar ordination could be used to predict how changes in these parameters might affect species distribution and abundance.

RECOMMENDATIONS

Our baseline data, and consequently our results, would have had more utility had we obtained them before construction began. Unfortunately, our initial field sampling occurred after some construction had begun.

Methods have recently been developed to provide before-and-after assessments in a shorter time frame and at less cost than the present study. Most notable of these is the U.S. Fish and Wildlife Services Habitat Evaluation Procedures (HEP). However, such methods are not designed to consider impacts to rare species or unique habitats. In these cases, direct surveys and measurements must be used.

Drift fence-pitfall trapping and transect counts are two conventional methods that can be easily and cheaply used to gather baseline data. When conducted over sufficient time, such methods effectively monitor and document impacts to terrestrial communities.

SECTION 3

DESCRIPTIVE STUDIES

INTRODUCTION

Construction began on portions of the Columbia site early in 1971. When the field studies began, construction workers had already cleared areas on which the main boiler stands and areas around the foot of the cooling lake, and had begun construction of what is now the west dike of the cooling lake, though originally it was intended to be the middle dike. At this time an attempt was made to describe the temporal and spatial distribution of approximately 500 species of plants and animals. It was impossible to do this directly for two reasons. First, this study began at the same time the construction began. Vegetation and animal species which previously existed in the areas destroyed had to be inferred from old records and rubble. Secondly, the approximately 1900 ha of the Columbia site and its surroundings constituted far too large an area for 3 to 4 investigators to cover in detail. The decision was made to concentrate on the distribution and description of plant communities followed by a detailed study of the animals associated with these communities. This was done by an intense census of samples of the most important and critical communities.

SUMMARY OF STUDIES OF TERRESTRIAL PLANTS

Methods

Several methods were used for the descriptive phase of the vegetation study depending on the nature of the problem. In most cases, aerial photographs were used to map the patterns of the communities. The plant communities were identified and named using Curtis (1959) as a guide. Notes taken from transects on foot indicated the nature of the community. These sorts of inventories involved some detective work in areas where the vegetation had been pushed over. In these areas the nature of the trees has to be inferred from stumps and piled logs.

Plant Communities Identified

Fifteen natural plant communities were identified. To these were added three very incomplete natural communities and traces of a fourth. The incomplete communities were Prairie, Fen, and Bog and the trace was of Northern Dry Forest. Each of the communities is outlined in Figure 3 and described in greater detail below.

While Curtis (1959) contains descriptions of each community, some of ours differed from his.

1. Open Water, (submerged aquatics) 235 ha, 11.5%. These were areas which have open water throughout the year. The most noticeable plants were the many species of *Myriophyllum* and *Potamogeton*.
2. Emergent Aquatic Communities, 358 ha, 17.4%. These areas were wet, with water at or near the surface most of the year. At Columbia they were well submerged during spring floods. *Typha latifolia* and *Sagittaria latifolia* were representative. *Lemna minor* was the most abundant plant in this community as well as in the open water and parts of the Southern Wet Forest.
3. Sedge Meadow, 662 ha, 32.1%. This community occurred in low, wet areas. The genus *Carex* was dominant. Sedge meadows naturally intergrade with emergent aquatic communities. On the Columbia site the area of intergradation is broad and intricate. This study did not appropriately define the ecotone between these two communities and wet prairie. In 1973, the study did not contain the resources to fund the careful study this distinction requires. This was unfortunately critical because the various dikes and ponds on the site strongly affected these wetland communities.
4. Shrub Carr, 34 ha, 1.6%. Shrub Carr, Fen and Alder Thicket were not distinct. Generally a sedge meadow with bushes growing, it was difficult to delineate a community from an occasional shrub. In this study all the shrubs were included in some community. Shrub Carrs here consisted of *Cornus* spp., usually *stolonifera*, and *salic* spp.
5. Alder Thickets, 12 ha, 0.6%. Alder Thickets are another wetland shrub community usually on subsurface calcareous drainage. Alders (*Alnus rugosa*) occurred in clumps in the sedge meadow and as edge plants in various situations.
6. Fen, 6 ha, 0.3%. This is a shrub community on mineral soil. It is probably more accurate to say the Columbia site had some scattered fen-like areas. *Betula sandbergii* was present in association with *Iris ssp.* and *Equisetum laevigatum*. But these latter species were found in other communities.

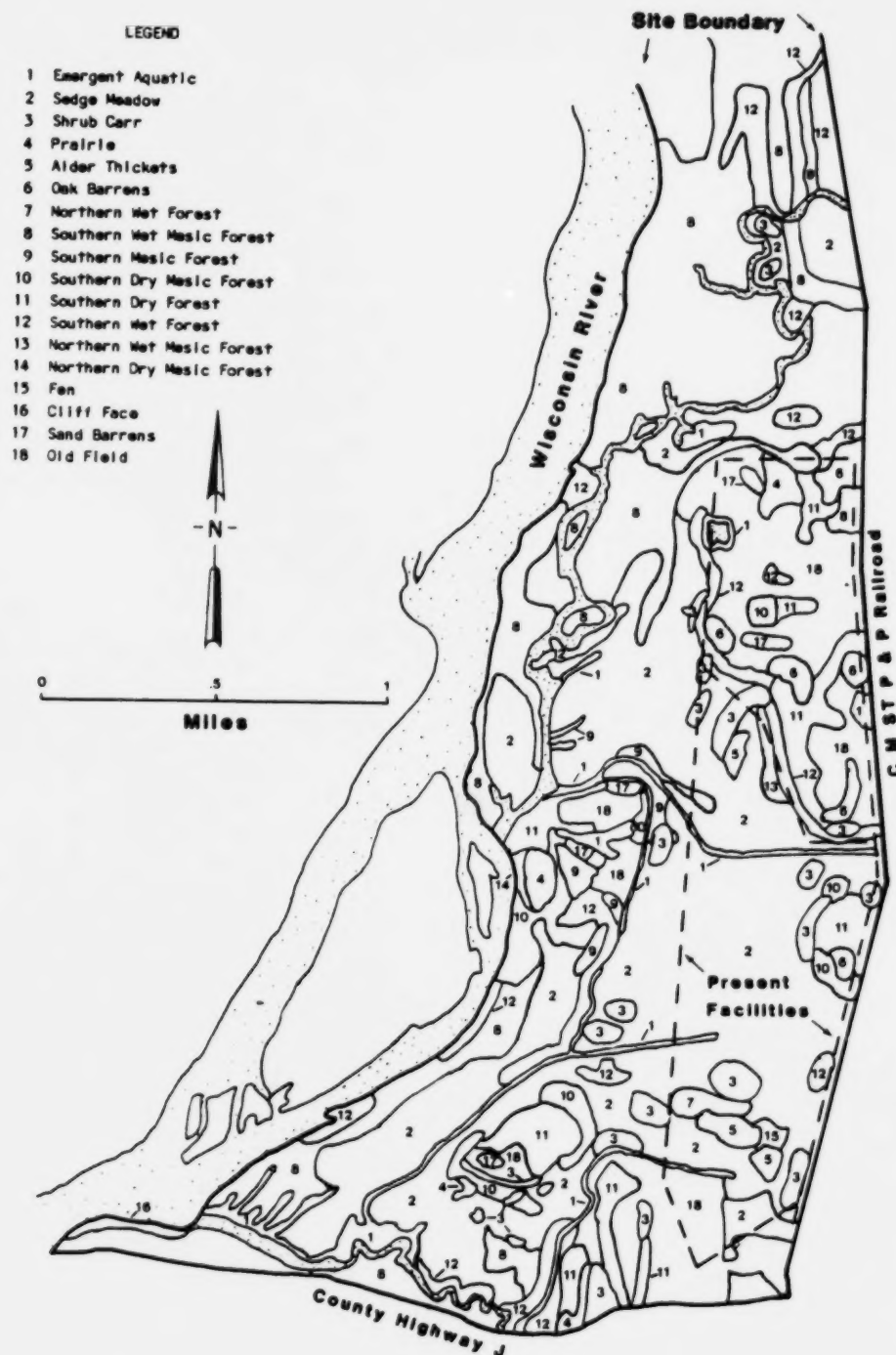


Figure 3. Plant communities identified at the Columbia Generating Station site.

7. Bog. The inventory showed no areas were distinguished as a Bog community though *Betula glandulosa* and several (4+) species of *Vaccinium* occur.
8. Prairie, 7 ha, 0.3%. In all cases "prairie" in this report means those communities derived from the succession of old fields. None of the so designated communities was free of weed species and all would probably be better called incipient mesic or dry prairies. There were, however, some areas along the western side of the Milwaukee Railroad tracks which contained large numbers of wet prairie species. There was a smooth gradient between open water and wet prairie across the site and lines between these communities was somewhat arbitrary.
9. Southern Wet Forest, 137 ha, 6.6%. These are lowland forests subject to frequent catastrophic flooding. *Salix nigra* with *Acer saccharinum* dominated.
10. Southern Wet Mesic Forests, 270 ha, 13.1%. One of the dominant communities on the site, these forests covered large areas of wetland. The dominant species was *Acer saccharinum* but it was well mixed, including *Ulmus americana*, *Fraxinus pennsylvanica*, and *Tilia americana* in the northern portions. This was one of the best developed tree communities on the site.
11. Southern Mesic Forest, 14.7 ha, 0.8%. It was thought that the lack of developed Southern Mesic Forest was primarily due to recent (20 to 30 years) disturbance. The communities investigated were well developed stands of *Tilia*, *Ulmus rubra* and *Quercus borealis*, with *U. rubra* dominant. On an aerial survey in September 1972 the brilliant fall color revealed a small stand of *A. saccharum* on the hills at the southern edge of the site. This discovery made the inclusion of this community much more satisfactory.
12. Southern Dry Mesic Forest, 92.5 ha, 4.5%. These were communities of high, well-drained places with *Q. borealis* dominant. Most of these communities appeared to be Southern Dry Forest. Had they remained undisturbed, they would have been succeeded by Southern Mesic Forests.
13. Southern Dry Forests, 69.6 ha, 3.3%. The Columbia stands seemed derived from oak openings because of the presence of old open-site oaks. The dominant species at Columbia were *Q. velutina*, *Q. macrocarpa* and *Q. alba*.
14. Northern Wet Forest, 1.7 ha, <0.1%. This, like the other Northern forests on the site was an incomplete community. The dominant tree was *Larix laricina* with *Alnus rugosa* and *Alnus verticillata*. The usual co-dominant in the northern part of Wisconsin is *Picea mariana*, but it was not found at Columbia.

15. Northern Wet Mesic Forest, 3.0 ha, 0.1%. This, as above, was only nominally a Northern community. The area was dominated by *Thuja occidentalis*. This was an infrequent species in the area. The community was cut and burned in August 1971.
 16. Northern Mesic Forests. No natural stands. There were several areas with a few scattered *Pinus strobus* with interspersed *Q. ellipsoidalis* that might well be Northern Dry Forest, but these were all areas of human impact and may have resulted from recent naturalization or cultivation.
 17. Oak Barrens, 19 ha, 0.9%. This community is transitional between sand barrens or old fields and oak opening. *Quercus ellipsoidalis* was present as scattered, stunted trees and *Hudsonia tomentosa* were widely scattered in the understory.
 18. Sand Communities. 23 ha, 1.1%. Curtis lists three sand communities in Wisconsin: sand bars, sand barrens, and sand dunes. The latter did not occur on the Columbia site, but the former two were well represented. They are vegetatively quite dissimilar. The sand barrens are any treeless areas derived from mismanagement of dry prairie. On this site sand barrens were characterized by *Hudsonia tomentosa* and *Andropogon gerardi*. The sand bars are along the streams of the site, primarily lower Rocky Run Creek and along the Wisconsin River. Characteristically they have little vegetation save young willows.
 19. Shaded Cliff Face. 18 ha, 0.9%. There is only a small area of cliff face along the south side of Rocky Run Creek just before it enters into the Wisconsin River. It is north facing along Rocky Run Creek and westward along the Wisconsin River. Predominant plants are: *Aquilegia canadensis*, *Campanula rotundifolia*, and *Cryptogramma stelleri*.
- NOTE: The following categories are our own though derived loosely from Bordner (1976). They are all communities, or rather, areas maintained for agriculture or residence.
20. Old Field. 81 ha, 3.1%. Grazing 3.9 ha, 0.2%. Classical studies of succession have dwelt upon the changes that take place as these communities evolve toward prairie seres. Many of the old fields on the Columbia site have not been plowed for several years. Others have not been plowed but were used for grazing until recently (1971).
 21. Active Agriculture. Domestic yards. These categories are common around the plant site but do not occur on it.

Changes in Plant Communities Size

Using aerial photographs taken in 1978 and 1979, plant communities were mapped. The same methods were employed as closely as possible as in the 1971 survey.

In 1973, a loss of 371 ha was predicted as a direct loss due to superposition of construction. It also was predicted that a larger area would be affected by erosion and alteration of drainage. As Bedford (1982) reports elsewhere, a considerable portion of this loss is sedge meadow. The data obscure the changes in habitat quality because of the quick recovery of Shrub Carr and Southern Wet Forest and the addition of new Open Water. Four communities were lost completely. Similarly these data tell little about changes in the relative abundance of species within a community (Table 1).

TABLE 1. CHANGES IN SIZE OF PLANT COMMUNITIES (ha) FROM 1971 TO 1979

Community type	1971	Area lost	Area gained	1979	Net change
Open Water	236	47	74	274	+27
Emergent Aquatics	358	68	21	311	-47
Sedge Meadow	662	481	0	181	-481
Shrub Carr	34	28	7	13	-21
Alder Thickets	12	12	0	0	-12
Fen	6	6	0	0	-6
Prairie	7	3	0	4	-3
Southern Wet Forest	137	63	91	165	+28
Southern Wet Mesic Forest	270	0	0	270	0
Southern Mesic Forest	15	1	3	18	+2
Southern Dry Mesic Forest	93	18	13	88	-5
Southern Dry Forest	70	54	0	26	-54
Northern Wet Forest	2	2	0	0	-2
Northern Wet Mesic Forest	3	3	0	0	-3
Oak Barrens	19	12	0	7	-12
Sand Communities	23	4	11	30	+7
Cliff Face	18	0	0	18	0
Old Field	81	71	15	35	-56
Total	2046			1408	-638

EARLY ANIMAL STUDIES

Introduction

Taking a census of different animals requires different techniques. Small fish are seined and trapped. Birds and amphibians are counted visually and acoustically. Small mammals are trapped. Large mammals and reptiles are counted visually and numbers are estimated by tracks, shed skins, and scat analysis.

Some 285 species of vertebrate animals have been documented to use the Columbia Generating Station site. The WDNR lists two additional fishes, the muskellunge and the walleye, bringing the total to 287 species (fishes 22, reptiles and amphibians 32, mammals 36, birds 197). Some of the usage is seasonal (geese, warblers, walleyes) and some of the animals are rare (muskellunge, sandhill cranes, otter). Many are seasonally very abundant (red-winged blackbirds, muskrats, chorus frogs, walleyes). The site contains a number of game species (white-tailed deer, ducks and northern pike).

Documenting environmental changes to animal populations is difficult for a number of reasons:

1. The sheer size of the Columbia Site (1900 ha) made coverage of the sum total of habitats difficult.
2. The elusiveness of certain species makes them difficult to observe.
3. Many species are subject to periodic oscillations in nature, some of which have a period of 4 or 5 yr. This requires long-term observation to distinguish natural versus man-induced fluctuations.
4. Animals move about in the site in response to their needs and to environmental change. For example, shrews move to higher ground to avoid floods. Thus, some areas of the site, that seem to be used lightly by animals are, in fact, refugia and essential to their survival.
5. Determining causal links for observed changes is seldom possible.
6. Determining the ecological significance of observed changes is difficult.

Following is a summary of general data and observations of mammals, reptiles and amphibians, and birds at the Columbia Site with discussions of changes observed during the project period.

Mammals

Mammals at the Columbia Generating Station were studied using a variety of qualitative and quantitative techniques. Direct observations along prescribed routes, or transects, were used to record the activities of larger mammals. Winter track counts along the same transects provided evidence of large and small mammal activities. Small box traps and drift fences were used along with mark-recapture analyses to estimate small mammal densities. Dropping boards also were used to estimate small mammal densities by scat analysis. Furbearers were studied using counts of muskrat dens and beaver lodges and by examining the records of trappers using the site.

Results--

A total of 36 species of mammals were observed at the Columbia Generating Station site during the study period (Table 2). Results of the small mammal trapping and tracking studies and the furbearer trapping records were reported previously by Jones (1975). Following is a discussion of several individual species and the changes observed in their populations at the Columbia Site.

White-tailed deer (*Odocoileus virginianus*) have historically used the Columbia Site as a migration corridor to get from upriver to downriver sites. The east bank of the Wisconsin River, on which an abandoned dirt road from Portage to Dekorra sits, provided a dry secure corridor for the deer until the water intake channel for the cooling lake was excavated through the North Knoll. At the urging of staff biologists and the WDNR, the utilities constructed two land bridges over the intake channel which the deer now use.

White-tailed deer also use the dry knolls on the Columbia Site as winter yards and have made trails in the successional vegetation of the dikes. Observations of trail use and movements of yarded deer indicate that they make use of heat released from the cooling lake which ameliorates the severity of winter temperatures.

Estimates of the deer population on the site show a reduction from approximately 80 to 100 individuals in 1971 to approximately 50 by 1977. Construction activities and the destruction of wetland and terrestrial habitats seem to be likely causes. The improved access to the site provided by construction resulted in additional impacts on the deer population due to hunting, which increased dramatically. In fact, all field work on the site was suspended during the yearly 10-day gun hunting season because of the high density of deer hunters.

Muskrat (*Ondatra zibethicus*) populations have varied greatly on the Columbia Site. In 1972, the muskrat population on the site was estimated to be approximately 1000. A 1973 survey showed only 50 muskrat dens in the wetland complex. Using an average of 5 muskrats/den (Jackson 1959), the

TABLE 2. MAMMALS OBSERVED AT THE COLUMBIA GENERATING STATION SITE
(1971-1977)

Order	Family	Species	Common name
Marsupialia	Didelphidae	<i>Didelphis marsupialis virginiana</i>	Opossum
Insectivora	Soricidae	<i>Sorex cinereus cinereus</i>	Cinereous shrew
		<i>Blarina brevicauda brevicauda</i>	Short tail shrew
	Talpidae	<i>Scalopus aquaticus machrinus</i>	Mole
Chiroptera	Vespertilionidae	<i>Lasiurus borealis</i>	Red bat
		<i>Myotis lucifugus lucifugus</i>	Little brown bat
		<i>Pipistrellus subflavus</i>	Georgian bat
		<i>Eptesicus fuscus</i>	Big brown bat
		<i>Lasiurus cinereus</i>	Hoary bat
Lagomorpha	Leporidae	<i>Sylvalagus floridanus</i>	Cottontail rabbit
Rodentia	Sciuridae	<i>Marmota monax</i>	Woodchuck
		<i>Citellus tridecemlineatus</i>	13 lined ground squirrel
		<i>Tamias striatus</i>	Eastern chipmunk
		<i>Sciurus carolinensis</i>	Grey squirrel
		<i>Sciurus niger</i>	Fox squirrel
		<i>Tamiasciurus hudsonicus</i>	Red squirrel
		<i>Glaucmys volans volans</i>	Flying squirrel
		<i>Castor canadensis</i>	Beaver
		<i>Reithrodontomys megalotis</i>	Harvest mouse
		<i>Peromyscus maniculatus</i>	Prairie deer mouse
		<i>Peromyscus leucopus</i>	White footed mouse
		<i>Microtus pennsylvanicus</i>	Meadow vole
		<i>Microtus ochrogaster</i>	Prairie vole
		<i>Ondatra zibethicus</i>	Muskrat
	Muridae	<i>Rattus norvegicus</i>	Norway rat
		<i>Mus musculus</i>	House mouse
	Zapodidae	<i>Zapus hudsonius</i>	Jumping mouse
Carnivora	Canidae	<i>Canis latrans</i>	Coyote
		<i>Tupes fulva fulva</i>	Red fox
	Procyonidae	<i>Procyon lotor</i>	Raccoon
	Mustelidae	<i>Mustela vison</i>	Skunk
		<i>Mephitis mephitis</i>	Striped skunk
Artiodactyla	Cervidae	<i>Odocoileus virginianus</i>	White-tailed deer

wetland population in 1973 can be estimated at approximately 250. During 1973, an additional population of muskrats congregated in dens burrowed into the banks of the drainage ditch running along the southern boundary of the site. No population estimate was possible. Few dens were observed in the wetland area during 1976.

Variations in muskrat populations most commonly are due to water level or other environmental changes, as the populations themselves do not conform to regular population cycles common in some of the smaller microtines (Jackson 1961). Prior to construction of the cooling lake, muskrats ranged throughout the wetland complex on the Columbia Site. Cooling lake construction eliminated over 200 ha of the muskrat habitat. Muskrats continued to inhabit the remaining wetland area although the dryer than normal summer and fall of 1973 probably contributed to the reduced population in the wetland. Leakage of water from the cooling lake has resulted in higher, more stable wetland water levels, increased open water areas, and an increase in the number of cattails (*Typha* sp.) relative to sedges (Bedford 1982). Such conditions tend to favor muskrat populations so it was expected that the muskrat population at Columbia would increase unless other factors (e.g. increased water temperatures) prove detrimental.

Reptiles and Amphibians

Introduction--

This section summarizes informal sighting and catches of reptiles and amphibians. Twenty-four species of reptiles and amphibians were encountered on or adjacent to the Columbia Generating Station Site. Of these, two are on Wisconsin's changing status list, namely a lizard--the six-lined race runner (*Cnemidophorus sexlineatus*)--and a snake--the eastern massasauga (*Sistrurus catenatus*).

Methods--

There are three methods generally used for observing, catching, finding, and identifying reptiles and amphibians. One method consists of simply turning over rubbish, logs, rocks, trash boards, etc., under which many of these animals like to rest. On the Columbia site, there was a considerable amount of waste wood from construction scattered throughout the site which makes good habitat, at least for resting places for these animals. Secondly, these animals, particularly the aquatic forms, often are found by seining and netting. In fact, such observations on the mud puppy (*Ambystoma maculosus*) were incidental to seining for aquatic invertebrates on Rocky Run Creek. Thirdly, many of these animals are caught during moist seasons of the year (spring and autumn) in fall traps which are placed next to long drift fences. These fences serve primarily to capture small mice, shrews and other species; and these species are discussed elsewhere in this

report. There is a fourth method, though not really a method so much as an incidental event accompanying other research activities, and that is just encountering the animals in their activities; flushing them out of the woods and other areas as you walk along. This included finding road kills of several reptile species, particularly on County Road JV to the south of the site.

Results and Discussion--

Table 3 lists the reptiles and amphibians that have been encountered on or adjacent to the Columbia Generating Station Site since 1971.

The occurrence of the species does not appear to be general throughout the site, and in some cases, the habitat where the species are found has been destroyed and no further specimens have been found. The *Ambystomatidae* salamanders are all found in fall traps or under litter in and about the v-shaped lake on the North Knoll. That lake has now been drained and the intake channel flows through it. However, three specimens of *Ambystoma laterale* have been found in camp traps since that date. The central newts (*Diemictylus viridescens louisianensis*) were all taken in the water as adults in Duck Creek at a point immediately adjacent to the North Knoll in the spring of 1973. *Necurus maculosus* has been found as a result of seining in Rocky Run Creek. The various toads and frogs were scattered throughout the site, but largely centered around the v-shaped lake, mentioned earlier, in small floodplain ponds in the woods near the North Knoll.

Considerable other habitat was in a pond now greatly truncated by the ashpit. *Rana pipiens* have been seen in the ashpit and the specimens in the ashpit seemed to have quite reddened and irritated skin, and several specimens were dead near the ashpit. This may well be due to the high alkalinity. A *Rana clamitans* was seen in the intake channel.

Generally speaking, all of the amphibian species seem to be reduced in numbers. This reduction of numbers is noticeable through the decrease of individuals one sees when moving about the site, and the reduction in the numbers one hears calling in the spring time, particularly from the highlands. One or two ponds have extremely dense populations of *Rana pipiens* tadpoles which may or may not mature in spring.

The three turtle species seem to be in waters throughout the site, particularly Rocky Run and Duck Creeks. They have been seen climbing several hundred meters up on to the sand barrens for breeding. In some areas on the South Knoll and in the sand barrens, there were as many as 20 or 30 nests in an area roughly 30 by 30 m (100 x 100 ft). Of the lizards, the six-lined race runner was seen on only two occasions on a sand barren area now covered primarily by the ashpit. Since the destruction of the sand barrens, there have been no sightings of this endangered species. The only specimen of the glass snake (*Ophisaurus attenuatus*) was found dead on County Road JV to the south of the site. The same is true of the western fox snake

TABLE 3. REPTILES AND AMPHIBIANS OBSERVED AT THE COLUMBIA GENERATING STATION SITE (1971-1977)

Family	Species	Common Name
Ambystomidae (Lunged salamanders)	<i>Ambystoma laterale</i> <i>Ambystoma maculatum</i> <i>Ambystoma tigrinum</i> <i>tigrinum</i>	Blue-spotted salamander Spotted salamander Eastern tiger salamander
Salamandridae (Newts)	<i>Diemictylus viridescens</i> <i>louisianensis</i>	Central newt
Plethodontidae (Lungless salamanders)	<i>Plethodon cinereus cinereus</i>	Red-backed salamander
Proteidae (Mud puppies and water dogs)	<i>Necturus maculosus</i> <i>maculosus</i>	Mud puppy
Bufonidae (Toads)	<i>Bufo americanus americanus</i>	American toad
Hylidae (Tree, cricket and chorus frogs)	<i>Hyla crucifer crucifer</i> <i>Hyla versicolor versicolor</i> <i>Hyla versicolor</i> <i>chrysoscelis</i> <i>Acris crepitans blanchardi</i> <i>Pseudacris triseriata</i> <i>triseriata</i>	Northern spring peeper Eastern gray treefrog Prairie or marsh gray treefrog Blanchard's cricket frog Western chorus frog
Ranidae (True frogs)	<i>Rana clamitans melanota</i> <i>Rana pipiens pipiens</i>	Green frog Northern leopard frog
Chelydridae (Snapping turtles)	<i>Chelydra serpentina</i> <i>serpentina</i>	Common snapping turtle
Emydinae (Wood, box and painted turtles)	<i>Emydoidea blandingi</i> <i>Chrysemys picta marginata</i>	Blanding's turtle Midland painted turtle
Teiidae (Whiptails)	<i>Cnemidophorus sexlineatus</i> <i>sexlineatus</i>	Six-lined racerunner
Anguidae (Glass lizards)	<i>Ophisaurus attenuatus</i> <i>attenuatus</i>	Western slender glass lizard
Serpentes (Suborder) (Snakes)	<i>Coluber constrictor foxi</i> <i>Elaphe vulpina vulpina</i> <i>Pituophis melanoleucus sayi</i> <i>Thamnophis sirtalis</i> <i>sirtalis</i>	Blue racer Western fox snake Bullsnake Eastern garter snake
Crotalinae (Pit vipers)	<i>Sistrurus catenatus</i> <i>catenatus</i> <i>Crotalus horridus horridus</i>	Eastern massasauga Timber rattlesnake



(*Elaphe vulpina*) and the bullsnake (*Pituophis melanoleucus*) Both were found dead on Road JV.

In 1971 and 1972, skins of these two species plus the blue racer snake (*Coluber constrictor foxi*) were seen on the southern part of the site, none were seen in recent years. The garter snake (*Thamnophis sirtalis*) is in wet areas throughout the site.

Of special interest are the two rattlesnakes reported to have been on the site. Two specimens of the eastern massasauga, *Sistrurus catenatus*, have been sighted at two places in the central portion of the site. The reported sighting of a group of timber rattlesnakes on fallen timber near Rocky Run Creek in the flood season can only be considered tentative.

Birds

Methods--

Birds were studied using a variety of methods at the Columbia Generating Station site. A set of five transects was regularly walked throughout the project period (Section 4). Direct observations were used in certain confined habitats (e.g., inside the cooling lake) or for certain conspicuous species [e.g., sandhill crane (*Grus canadensis*), harrier (*Circus cyaneus*)] to estimate population sizes. Incidental observations, made while conducting other activities, aided in identifying new species and in observing behavioral activities (i.e., nesting, feeding).

Results--

A total of 197 species of birds were observed at the Columbia Generating Station site from 1973 to 1977 (Appendix A). This total represents permanent residents, seasonal residents, migratory visitors, and species utilizing transitional habitats (while they existed) created by construction activities.

The dominant impact affecting birds at the Columbia Site was the construction and filling in of the cooling lake. The 200 ha wetland area inundated by cooling lake water supported a great many bird species. It was estimated that the cooling lake displaced approximately 1300 nesting red-winged blackbirds (*Agelaius phoeniceus*) when it was filled in June of 1974, during the middle of their nesting season. Other species (e.g., sora rail (*Porzana zonalis*), Virginia rail (*Rallus limicola*), and American bittern (*Botaurus lentiginosus*) were affected similarly. Species that used the wetland complex for feeding also were displaced. A pair of harriers (listed as a 'changing status' species in Wisconsin) had foraged in the wetland complex the previous 2 yr but were not seen in the years following cooling lake filling. Likewise, a large colony of great blue herons (*Ardea*

herodias) which also had used the Columbia wetlands for foraging gradually disappeared following the filling (Section 5).

Before the cooling lake was filled in 1974, spring runoff had collected within the dikes to create a deep-water marsh habitat complete with floating peat mats. A small population of 30 black terns (*Chlidonias nigra*) took advantage of this transitional habitat and nested on the floating mats. This was the first record of black terns nesting on the Columbia site. Nesting was a success as the adults were able to rear the young before the water level rose to the point of breaking up or sinking the mats.

Prior to the creation of the cooling lake, waterfowl activity was primarily limited to the sloughs of Duck and Rocky Run Creeks, where a sizable wood duck (*Aix sponsa*) population nested and which served as a stopover for migrating Canada geese (*Branta canadensis*). In addition, some blue-winged teals (*Anas discors*) nested in the wetland complex.

But the creation of the cooling lake, while eliminating some of the wetland, also attracted thousands of migratory ducks. Twenty-two species of waterfowl were observed using the cooling lake during the spring of 1975, including state-endangered double-crested cormorants (*Phalacrocorax auritus*). A complete count of species present during four weekly visits during spring migration showed that the most abundant species on the cooling lake at any one visit were scaup (2314 individuals) followed by coot (*Fulica americana*) (350), ruddy ducks (*Oxyura jamaicensis*) (210), and ring-necked ducks (*Aythya collaris*) (202), canvasback (*Aythya valisineria*) (96), horned grebe (*Podiceps auritus*) (75), and American merganser (*Mergus americanus*) (62). At this time, the generating station was running boiler tests so no thermal gradient had yet been established in the cooling lake.

During the spring 1976 migration, when a total of 17 species were recorded, the most abundant species observed on the cooling lake at any one time during four weekly counts were coot (1690), ruddy ducks (200), scaup (162) and bufflehead (*Bucephala albeola*) (16). The coot population was up sharply and nearly all other species, particularly scaup, were reduced in numbers. Except for the coot, which were found mostly near the station's outfall where water temperatures in the lake ranged from 20.5 to 21.7°C, most species were observed using the coolest portion of the lake near the intake, where temperatures ranged from 11.8 to 14.5°C.

Several explanations for the drop in migratory waterfowl use of the cooling lake in 1976 are possible. The spring of 1976 was very wet and created a number of ephemeral ponds in the area. These ponds could have attracted waterfowl that otherwise would have used the cooling lake. It is also possible that in-lake temperatures or water quality characteristics were not optimum for the waterfowl once the cooling lake was in use. Because research efforts had to be directed elsewhere, follow-up studies in subsequent years could not be made. Additional studies of the use of the cooling lake by migrating waterfowl are recommended.

General disturbances caused by construction activities (noise, off-road vehicle traffic, constructing and maintaining new roads) have probably

contributed to the reduction in numbers of species less tolerant to disturbance. For example, harriers, great blue herons, American bitterns, sandhill cranes, and some of the rarer species that had their habitat requirements only marginally met on the Columbia site. Of particular interest was the disappearance of sandhill cranes from the site. Groups of up to five of these magnificent birds ranged throughout the wetland complex in the years prior to cooling lake filling, and a pair of these cranes had nested in the wetlands to the west of the cooling lake during 1972 and 1973. No nesting activity was documented on the site for 1974 to 1977, although occasional visitors were observed. The sandhill crane is a species which requires large, open and generally undisturbed areas for nesting and feeding. The construction activities at Columbia apparently modified these requirements to the extent which eliminated the cranes from the site.

SECTION 4

TRANSECT COUNTS TO DOCUMENT THE IMPACTS OF ENVIRONMENTAL CHANGES IN BIRDS

INTRODUCTION

The extensive study of bird populations at the Columbia Generating Station site was undertaken to further the early descriptive work by developing quantitative data to help document changes to birds resulting from construction and operation of the plant. The transect study was conducted from January 1973 to the fall of 1976.

LITERATURE REVIEW

Two approaches are useful in determining bird abundance. One involves determining an index of relative abundance; the other estimating the absolute population density. Kendeigh (1944) discusses a number of methods used in determining relative abundance of birds. In these methods, populations may be sampled over random courses or on established transects from which the frequency or rate of occurrence can be calculated. In both calculations, assumptions must be made which limit the usefulness of the data. In determining frequency, it is assumed that the most abundant species will be more widely dispersed, and therefore will be encountered more frequently. In determining the number of species observed with time, little can be said of the spatial distribution of the observed species.

Direct counts of flocking species and various non-flocking birds living in exposed situations are possible within circumscribed and measured areas but are generally ineffective for the majority of non-flocking birds found in more densely vegetated habitats. The use of direct counts also is limited by the size of the area to be sampled and tends to be time inefficient. Emlen (1971) developed a method utilizing coefficients of detectability and is useful in many cases. However, it does have limitations for certain species and for non-uniform or dynamic habitats where many coefficients of detectability must be computed for each species. The variable-strip transect method (Emlen 1977), bypasses the coefficients of detectability in favor of determining for each species, "the strip width along the trail within which a fully alert observer will detect essentially all cues that are produced." Total counts from within this strip are combined with measured cue frequencies (in the breeding season) to derive density values. The reliability of the method depends on the

completeness of the count close to the trail and on an even distribution of species laterally from the trail. These assumptions may be difficult to control during the non-breeding season or in non-uniform habitats.

Most field methods used to determine either relative or absolute densities have additional limitations associated with observational variables which can include: 1. the experience, acuity, attentiveness, and speed of advance of the observer; 2. the observation conditions related to weather, time of day, etc; 3. the screening effect of the habitat; and 4. the conspicuousness of the birds as related to their calls, movements, size, and color (Emlen, 1971). These variables must be controlled appropriately in order to achieve the desired level of effectiveness that any given field method possesses.

Since most bird communities are composed of species that represent a broad spectrum of ecological and physiological adaptations, an equally broad spectrum of responses would be likely when a diverse bird community is subject to environmental change. Population level studies could be most valuable under these circumstances because they can carry more information than species level studies. However, the large size and diverse vegetation of the study area presented some practical problems to conducting such a population study. After considering and testing several sampling methods, a transect system was established which combined features of the strip and plot census methods described by Kendeigh (1944).

FIELD METHODS

Five permanent transects, varying from 2.5 to 3.2 km each in length, made up the sampling system (Figure 4). Each transect had 17 to 18 observation stations, 0.25 ha (2500 m²) in size. The stations were established so that all the major plant communities and many community edge types would be sampled. Vegetation cover maps were drawn for each station showing distribution of cover and understory species as well as the percent cover of dominant species. See Jones (1975) for station cover maps. Each station was categorized with a numerical code based on the following broad communities (Curtis 1959):

1. Open water
2. Emergent aquatic
3. Sedge meadow
4. Shrub carr
5. Southern wet forest
6. Southern wet mesic forest
7. Southern dry forest/southern dry mesic forest
8. Sand barrens
9. Old field

The habitat code for each of the observation stations is given in Table 4. Stations having codes with two numbers represent edges between the two communities.

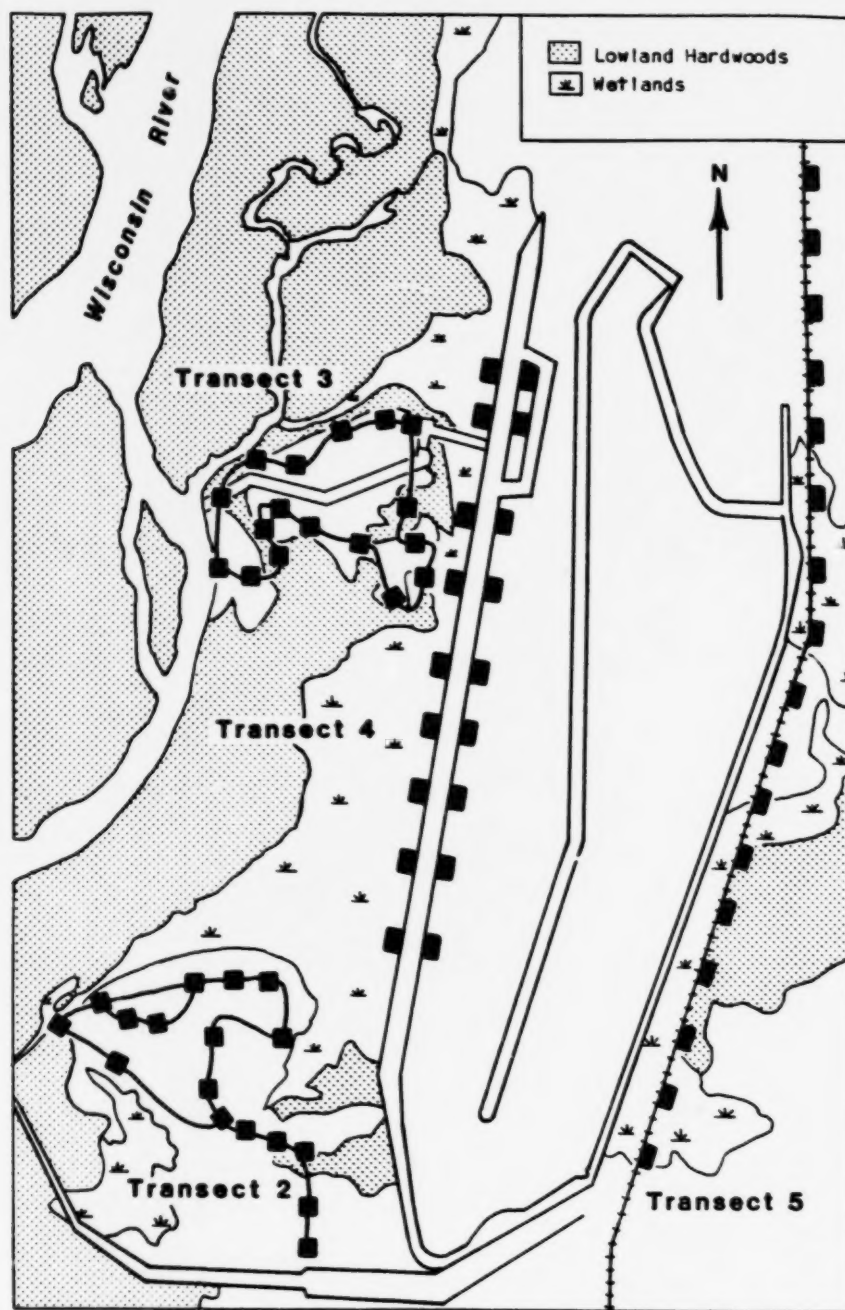


Figure 4. Location of Bird Transects. Transect 1, at the extreme northern edge of the site is not illustrated.

TABLE 4. HABITAT DESIGNATIONS OF THE BIRD OBSERVATION STATIONS

Transect/ Station No.	Habitat Code	Transect/ Station No.	Habitat Code	Transect/ Station No.	Habitat Code
101	46	301	79	501	07
102	06	302	09	502	59
103	06	303	07	503	69
104	36	304	09	504	34
105	06	305	07	505	27
106	06	306	07	506	34
107	06	307	07	507	09
108	06	308	09	508	34
109	36	309	07	509	07
110	16	310	67	510	09
111	06	311	67	511	34
112	06	312	68	512	34
113	06	313	16	513	46
114	06	314	79	514	34
115	36	315	36	515	34
116	06	316	09	516	03
117	06	317	69	517	79
118	16			518	79
201	09	401	34		
202	09	402	34		
203	67	403	34		
204	06	404	03		
205	67	405	34		
206	07	406	34		
207	79	407	03		
208	09	408	03		
209	07	409	34		
210	07	410	03		
211	07	411	03		
212	07	412	03		
213	08	413	03		
214	07	414	03		
215	07	415	13		
216	79	416	13		
217	78	417	34		
		418	03		

A sample count was made by an observer spending 3 min walking through a station on its centerline, using visual and song cues to record all birds seen within the boundaries of the station. The observer proceeded to sample the rest of the stations in that transect. The 3-min sampling period was determined to provide sufficient time to observe and record all species within a station. Birds flushed from a station upon entry were counted but species flying high overhead (e.g. ducks), were not counted. No attempts were made to attract bird calls, however, elusive species within a station could be flushed to aid in identification.

Sampling of the transects began in the spring of 1973 and continued through the fall of 1976. Each transect was sampled approximately every 10 days from April to October and every 20 days during the remainder of the year. Sampling was initiated within 5 to 20 min after sunrise. All observers were screened in order to maintain a high level of accuracy in the study.

STATISTICAL METHODS

During the 4 yr of the study, more than 400 samples were made of the transects resulting in nearly 7000 station observations. This created a sizable data base which required the use of several methods of interpretation and analysis including: mean analysis, species diversity, and polar ordination.

Mean Analysis

The 95% confidence intervals were calculated around the mean number of birds observed in each of the 88 observation stations. A 95% confidence interval is one which will fall over the mean 95% of the time. This technique was used to provide a station-by-station account of how sample means behaved with time with regard to specific construction activities.

The "Student's t" distribution was used to calculate the confidence intervals. The form of the confidence interval for the mean is simply $\bar{X} \pm (n-1)(s/n)$.

where:

$\bar{X}$ = the sample mean

s = the sample standard deviation

n = the sample size

(n-1) = the value of t found in a table of the Student's t distribution with (n-1) degrees of freedom (Ryan et al. 1976).

The t-test is particularly useful for testing differences between two biological samples because it is relatively insensitive to deviations from normality (Simpson et al. 1960). This is an advantage since no real population is ever "exactly" normal. However, in order to gain this flexibility, the test sacrifices some of its power. Despite this, it is still useful to illustrate some sample characteristics.

To test whether the sample population means are significantly different, a difference between two means test was applied to selected pairs of means. The test assumes an independent random sample. It also contains an expression to correct for a small sample size. The test used is the following (Blalock 1972):

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - D}{\hat{\sigma}_{\bar{x}_1 - \bar{x}_2}} = \frac{(\bar{x}_1 - \bar{x}_2) - D}{\frac{N_1 S_1^2 + N_2 S_2^2}{N_1 + N_2 - 2} \cdot \frac{N_1 + N_2}{N_1 N_2}} \quad (1)$$

where:

$D = 0$ (given from the H_0)

$\bar{x}_1$ and $\bar{x}_2$ = the two groups means

$\hat{\sigma}_{\bar{x}_1 - \bar{x}_2}$ = estimate of the standard error of the difference between sample means

N = sample size

S^2 = sample variance

For the test, a null hypothesis (H_0) was used which stated that there is no difference between the true means of the two groups of data. The groups of data in this case are two different years of data for the same station.

The calculated t value is compared with a t value in a t distribution table using $(N_1 + N_2 - 2)$ degrees of freedom. If a calculated value is greater than the table value, there is a significant difference between the two means at the level tested. For this study, values were tested at the 95% level of probability. Values were judged significant if they exceeded the 95% level.

Species Diversity

Of the total number of species in a community, a relatively small percentage are abundant and a large percentage are rare. While the few

common or "dominant" species usually account for much of the energy flow in the community, it is the large number of rare species that largely determines species diversity. Species diversity can be defined as a function of the number of species present (species richness or species abundance) and the evenness with which the individuals are distributed among the species (species evenness) (Odum 1971; Krebs 1972; Poole 1974).

Much speculation and some generalization concerning the role that species diversity plays in community stability, succession, and total productivity is evident in the literature. Loucks (1970) reviews some of the theories. It remains unclear whether diversity and stability are generally related. In the midst of this continuing discussion, Hill (1973) reminded us that diversity indices are mere numbers and should be distinguished from the theories which they support. Species diversity should be regarded as a measurable property whose observed values may be explained by a variety of theories.

There are a number of ways to determine species diversity. Early investigators simply used the number of species per sample as an index of its diversity (Dickman 1968). However, this method failed to distinguish between samples in which the relative abundance of the different species also differed. New indices were devised and refined to such an extent that today, there are a large number of diversity indices to choose from. Separate indices have been suggested for large and small samples, random and non-random populations, and the instances when the total number of species is known or unknown (Pielou 1966b).

Of the available species diversity measurements, the widely used Shannon-Weaver (1963) function (H') was chosen. This function combines richness and evenness components into one overall index of diversity. It involves the use of information theory for an analysis of community organization. The function measures the uncertainty of predicting the species of an individual, drawn at random from the entire population of individuals of several species. The form of the equation is:

$$H' = - \sum_{i=1}^N \left(\frac{X_i}{T} \right) \ln \frac{X_i}{T} \quad (2)$$

where:

N = total number of species

T = total number of individuals

X_i = number of individuals of the i th species.

H' is most effective as an estimate of total population diversity with a random sample where most of the species available have been included.

The Shannon function is an arbitrary measure and this must be considered in its application. A problem with all diversity measures has been in determining the appropriate relative weights to be given to species richness, species abundance, and species evenness. And since diversity has never had a single, unequivocal definition, there has been no objective way to assign these relative weights (Hurlbert 1971). Because of this, complaints that the Shannon function is inadequate because it attaches more weight to relative abundance and less to species richness (Sager and Hasler 1969) are not totally valid.

As a measure of the evenness with which individuals are distributed among the species, the following expression was used (Pielou 1966a):

$$J' = H'/H'_{\max} \quad (3)$$

where:

$$H'_{\max} = \log_2 N$$

N = the number of species in the sample.

The index represents the ratio between the observed diversity and the maximum possible diversity for the same number of species. It has a maximum value of unity when all species are equally abundant, and a minimum value when all species but the most abundant one, are represented by only one individual.

Ordination

Multivariate analysis was used to study changes in the composition and structure of the bird communities. This technique is designed to detect pattern in masses of data when many attributes of many objects have been sampled. In the present study, the objects are stands within communities and the attributes are species which occurred in them. Two basic approaches are used in multivariate analysis--classification, which arranges communities into discrete units, and ordination, which arranges communities along a continuum. Of the two methods, ordination was chosen because generally it will provide more insight into interrelationships among objects or attributes (Beals, 1973).

Ordination expresses variation by the calculation of interstand distances for all pairs of stands using a coefficient of similarity. These differences are used to place sites on axes. By interchanging ordination algorithms, any number of ordination methods are possible. After considering several of these, polar ordination, similar to that described by Bray and Curtis (1957) for plants, was used.

Bray-Curtis ordination is a versatile technique that performs well when data show a wide range of variation. When compared to more mathematically elegant techniques such as principal components analysis, Bray-Curtis ordination gave better and more ecologically interpretable results (Bannister 1968; Gauch and Whittaker 1972; Beals 1982). In addition, principal components analysis makes a number of unrealistic assumptions about the distribution of the data (Beals, 1973, 1982).

Before applying the Bray-Curtis ordination, the raw field data were standardized. This was necessary because there were different numbers of observations for the different stands. Without standardization, the first axis on the ordination would simply reflect the number of observations in each stand. A computer program for polar ordination, written by members of the University of Wisconsin Botany Department (Post et al., unpublished), was available on magnetic tape.

Distance Measure--

In order to determine the distance between each stand, a coefficient of similarity was used:

$$C = 2w/a+b \quad (4)$$

where:

a = the sum of abundance values of all species in one stand

b = the sum of abundance values of all species in another stand

w = the sum of abundance values that the two stands have in common for each species.

As an example, consider the following two stands.

	<u>Stand 1</u>	<u>Stand 2</u>	<u>Common Species</u>
Species A	5	1	1
Species B	2	7	2
Species C	10	6	6
	<u>a = 17</u>	<u>b = 14</u>	<u>w = 9</u>

$$C = \frac{2w}{a+b} = \frac{2(9)}{17+14} = 0.58 \quad (5)$$

As calculated by the formula, the two stands have a similarity of 0.58. The value of the coefficient ranges from zero, if the stands have no species in common (maximum distance) to 1.00 if the stands are identical (minimum distance).

In this ordination, stands were arranged according to their relative dissimilarity, so inverse values of the coefficients of similarity were used, subtracting the coefficient from 1.00. The interstand distances calculated by the dissimilarity index were set into an $m \times n$ distance matrix

where:

m = the number of species

n = the number of stands.

These distances were used to place the stands on axes.

This dissimilarity coefficient has been criticized because it does not conform to Euclidian geometry (Austin and Orloci 1966). For example, the distance between A and B could, using this coefficient, be greater than A to C and B to C - in other words, a triangle whose hypotenuse is longer than the sum of the other two sides (Allen 1970). This situation has been avoided by relativizing the data (Beals 1973).

This distance measure has in fact, been used successfully in other studies (Curtis 1959, Beals 1960). When it has been compared to Euclidian distance, many authors (Bannister 1968, Gauch and Whittaker 1972, Beals 1973) have found that C gave more ecologically interpretable results (See Beals (1973) for theoretical justification).

Axis Construction--

In polar ordination, each axis is drawn between two stands which are the endpoints of the axis. If stands are represented as points in space whose coordinates are the individual species scores, it is possible that a maximum of $(n-1)$ axes would be necessary to account for all distances between n stands. Reducing the number of axes can be accomplished by generating a limited number of new axes positioned to account for a large portion of the interstand distances. When stands are plotted on these axes, the resulting scatter diagrams represent a projection of the multidimensional point cluster into a space defined by the ordination axes (Austin and Orloci 1966).

Several options are available for selecting endpoints. Bray and Curtis (1957) used the two most dissimilar stands as the reference points for their axes. Using this method, peculiar stands isolated from the main cluster of samples, can distort the actual differences because the first axis merely reflects the difference between the peculiar stand and the main cluster, and little else. As additional axes are generated in Bray-Curtis ordination,

they originally are not perpendicular to each other, although they are treated as such. Austin and Orloci (1966) have severely criticized the Bray-Curtis method for these reasons.

For this study, the variance regression method suggested by Beals (1982) was used. The variance of the distances of each stand with every other stand is calculated (excluding all $d = 0$). The stand with the greatest distance variance becomes the first endpoint. Regression coefficients are calculated between the row of distances that represent the first endpoint (independent variable) and each other row in the distance matrix (dependent variable). The stand with the lowest regression coefficient is selected as the second endpoint. The remaining stands are projected onto the axis based on their distances from the two endpoints. The first axis accounts for a part of the total variation present in the community.

A second axis is constructed to account for more variation. A new matrix of residual distances, not accounted for by the first axis, is calculated. The whole procedure of endpoint selection is repeated to construct the second axis. Additional axes can be constructed in this way although most of the variation is accounted for in two or three axes. The use of a residual distance matrix to determine each succeeding axis avoids the problem of nonperpendicular axes encountered with the original Bray-Curtis method.

Procedure--

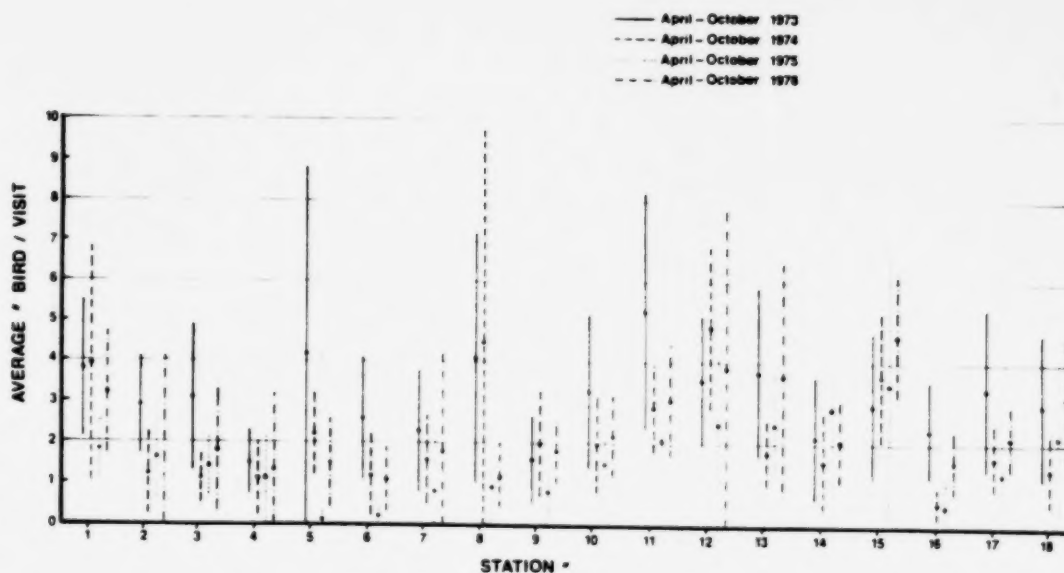
Bird community composition data for 66 of the 88 observation stations in the study area were ordinated. The stations used represent seven different habitat-types. The remaining 22 stations were not included in the ordination because they either had too few data points or they were the only examples of additional habitats. "Between-habitat" ordinations, using data from the 66 stations, were used to separate differences between habitats based on their avian populations. "Within-habitat" ordinations were conducted on the stations of each individual habitat. These ordinations were designed to illustrate how the avian community in a particular habitat responded to change with time. Only data collected during June and July were ordinated since this period represents the stable breeding season for most species of birds.

DATA AND ANALYSIS

Mean Analysis

Bar graphs showing 95% confidence intervals about the sample population means for all observation stations for the 4 yr of the study are given in Figure 5. The difference between two means test are given in Table 5. There are a number of cases where the difference between two sample means is

TRANSECT '1 - LEVEE



TRANSECT '2 - SOUTH KNOLL

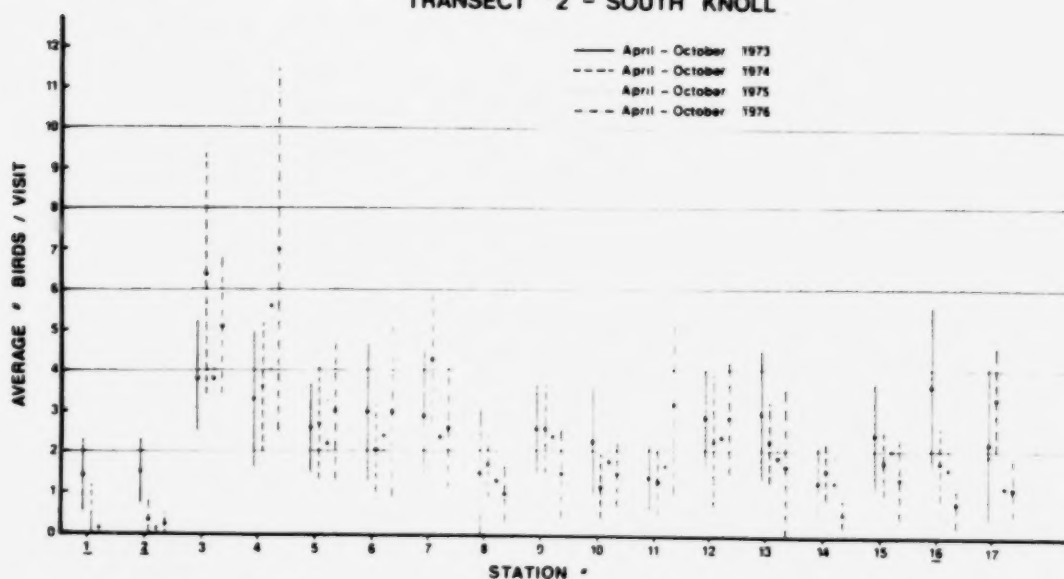
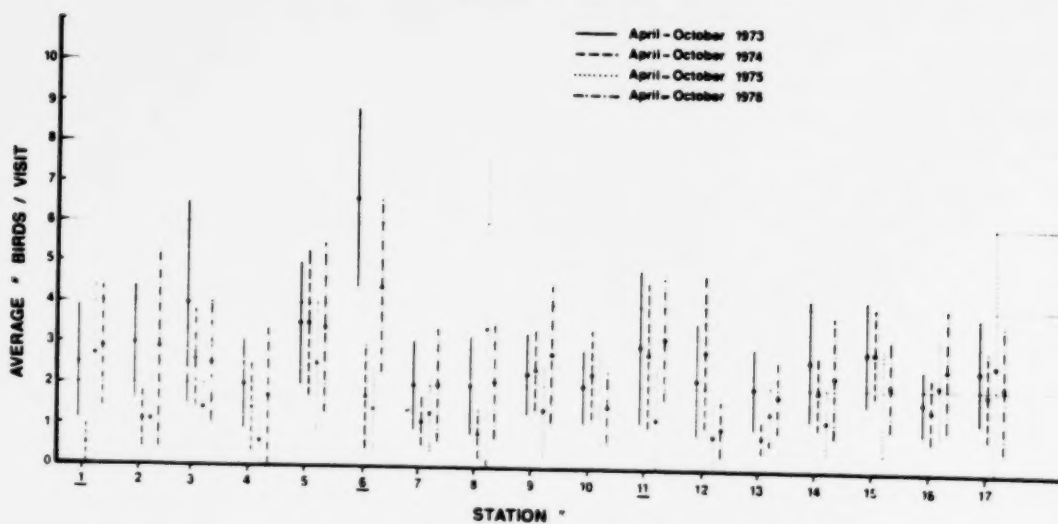


Figure 5. Mean number of birds observed in each station for the four years of study. 95% confidence intervals are depicted by the bars. (continued)

TRANSECT '3 - NORTH KNOLL



TRANSECT '4 - WEST DIKE

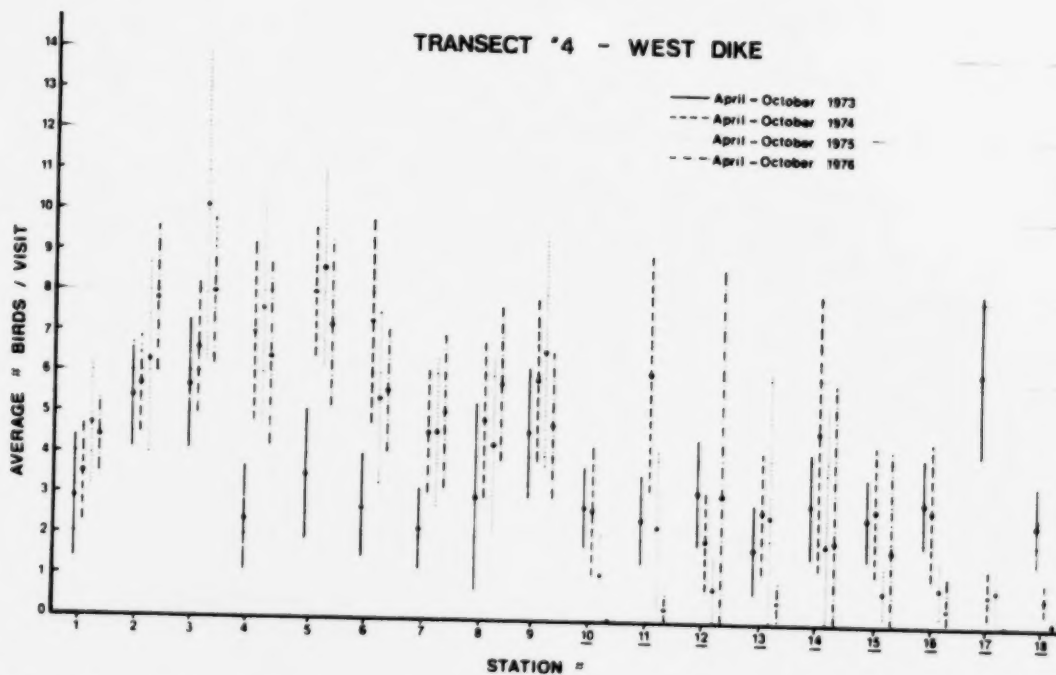


Figure 5. Mean number of birds observed in each station for the four years of study. (continued)

TRANSECT #5 - RAILROAD TRACKS

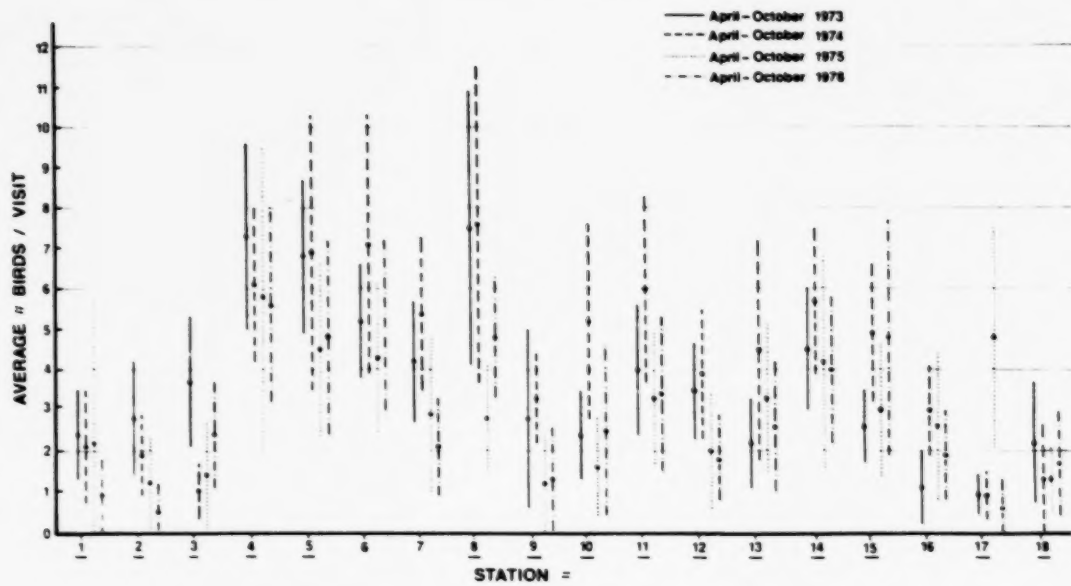


Figure 5. Mean number of birds observed in each station for the four years of study.

TABLE 5. RESULTS OF A TEST OF DIFFERENCE BETWEEN TWO MEANS APPLIED TO
SELECTED STATIONS, $\alpha = 0.05$

Station No.	Group tested	Calculated t value	Results
102	1973, 1975	1.54	Not significant
106	1973, 1975	2.71	Significant
108	1974, 1975	1.21	Not significant
111	1973, 1975	2.09	Significant
116	1973, 1975	2.88	Significant
201	1973, 1975	2.92	Significant
202	1973, 1975	2.92	Significant
203	1973, 1974	1.84	Not significant
203	1974, 1975	1.66	Not significant
213	1973, 1975	0.89	Not significant
216	1973, 1975	1.70	Significant
217	1974, 1975	2.74	Significant
301	1973, 1974	2.88	Significant
301	1974, 1975	2.71	Significant
302	1973, 1974	2.39	Significant
303	1973, 1975	1.90	Not significant
306	1973, 1975	4.64	Significant
403	1973, 1975	2.57	Significant
404	1973, 1975	2.57	Significant
405	1973, 1975	2.57	Significant
406	1973, 1975	2.48	Significant
407	1973, 1975	2.62	Significant
409	1973, 1975	1.52	Not significant
410	1973, 1975	2.29	Significant
412	1973, 1975	2.86	Significant
415	1973, 1975	2.76	Significant
416	1973, 1975	2.93	Significant
417	1973, 1975	3.77	Significant
418	1973, 1976	3.49	Significant
501	1973, 1975	0.26	Not significant
502	1973, 1976	2.50	Significant
507	1973, 1976	2.05	Significant
508	1973, 1975	2.20	Significant
517	1973, 1975	3.34	Significant

significant. The cause of the difference is not always easy to explain, however analysis has shown many of the changes to be related to construction activities. The rather large confidence intervals probably attest more to the variable nature of the bird observations than to anything else.

Transect 1--

In these stations a general decrease in sample mean between 1973 and 1975 was followed by an increase in 1976. In several cases, the decrease is statistically significant. Transect 1 is located 3 km north of the construction site so it is unlikely that plant construction would have caused the decrease. Summers of 1973 and 1976 suffered from extreme drought in Wisconsin. The droughty conditions in those years may not have affected the stations, most of which are in wet or wet mesic forest habitat, as severely as upland sites. More favorable conditions in the lowland areas could have attracted species from other habitats, causing the higher densities.

Transect 2--

Stations 207 to 215 are located in undisturbed and generally forested areas. Population means in these stations exhibit changes that are nonsignificant. Stations 203 to 206 and 216 to 217 lie along a dirt road frequently used by construction vehicles. Data indicate that some of the changes in these stations are significant. Stations 201 and 202 had highly significant decreases in sample mean after they were cleared of all vegetation in the spring of 1974. Station 216 is within an area of mixed oaks that was used for disposal of dredge spoils in 1974. The subsequent increase in soil levels caused the stand of oaks to die out. This probably accounts for the observed decrease in sample population mean.

Transect 3--

Construction activity was quite heavy in and around Transect 3. An intake structure and a pump house were constructed during 1974 in stations 306 and 301, respectively. During the same year, an intake channel for lake make-up water was dug adjacent to or through stations 304, 306, 311, and 312. The initial changes in stations 301 and 306 are quite significant but the sample population means later returned to pre-disturbance levels. The stations adjacent to the intake channel show a somewhat similar response. The short-term nature of the decline in sample means indicates that the birds were responding to the construction activity rather than to the permanent structure.

Transect 4--

Stations 410 to 418 were inundated with water when the cooling lake was filled during the summer of 1974. The highest means for these stations occurred during this slow lake filling process when less common species, including black terns, numerous shorebirds, and a pair of double-crested cormorants, were attracted to floating peat mats and other features of the newly formed lake. The change from sedge meadow to open water habitat resulted in a significant decline in sample means in many of the stations. The confidence intervals also increased following inundation probably due to the variable distribution and movements of waterfowl. At the same time, the sample means for stations 401 to 409 increased. An influx of species from the flooded portion of the wetland may have contributed to this.

Transect 5--

In late 1974, a 15 to 20 m swath was cleared through the center of all stations in Transect 5 for a transmission line right-of-way. Forested habitats suffered greater damage than the old field or wetland areas, however, nearly all stations show a drop in sample population mean in the following years. In several cases, this drop is significant.

Species Diversity

Using Shannon's function (H'), species diversity and evenness was calculated for all species for June and July of 1973 to 1976. the June and July data were again used since this period was judged to be representative of the breeding season. Results are presented in Table 6.

Trends in H' and S from one habitat to another are similar, with the impacted stations generally having lower values than the non-impacted stations. Values for N and N/V show similar trends in most habitats. Evenness values varied without direction in most habitats, however, values in the less severely impacted stations often remained equal to or were greater than those for non-impacted stations for the same year and habitat.

Among the habitats, wetlands and old fields had slightly lower H' values for impacted and non-impacted stations. Stations in the shrub carr/wet mesic forest edge had the lowest diversity of all habitats.

Ordination

Table 7 gives a summary of presence values for the 27 species of birds studied. Percentage presence is the number of stations of occurrence of a species in a given habitat, expressed as a percentage of the total number of

TABLE 6. SUMMARY OF COMMUNITY DATA FOR BIRDS IN SEVEN HABITAT TYPES SAMPLED DURING JUNE AND JULY OF 1973 TO 1976; WHERE S = SPECIES RICHNESS, N = SPECIES ABUNDANCE, N/V = NO. OF INDIVIDUALS PER SAMPLE, H' = DIVERSITY, AND J' = EVENNESS ($J' = H'/\ln N$)

Habitat	Year	S	N	N/V	H'	J'
Sedge Meadow						
Non-impacted	1973	11	51	2.1	2.03	0.84
	1974	20	175	6.3	2.13	0.71
	1975	15	100	5.9	2.01	0.76
	1976	20	127	5.3	2.49	0.83
Impacted	1973	16	52	2.6	1.67	0.60
	1974	22	102	2.1	2.43	0.79
	1975	3	5	0.2	1.05	0.96
	1976	1	4	0.1	0.00	--
Wet Mesic Forest						
Non-impacted	1973	30	173	2.7	2.95	0.87
	1974	29	162	3.1	2.82	0.84
	1975	32	136	3.2	3.21	0.92
	1976	38	210	2.3	3.07	0.84
Dry Forest						
Non-impacted	1973	28	88	1.7	2.98	0.89
	1974	25	98	1.8	2.90	0.90
	1975	32	135	2.0	3.04	0.80
	1976	28	176	2.7	2.89	0.87
Impacted	1973	22	54	2.3	2.83	0.92
	1974	16	36	2.1	2.46	0.89
	1975	14	33	1.7	2.35	0.89
	1976	21	54	2.3	2.71	0.89
Old Field						
Non-impacted	1973	21	112	3.3	2.46	0.81
	1974	14	57	2.0	2.24	0.85
	1975	19	103	3.2	2.34	0.79
	1976	17	71	2.0	2.52	0.89
Impacted	1973	10	25	1.8	2.02	0.88
	1974	9	22	1.6	1.98	0.90
	1975	6	10	0.5	1.61	0.90
	1976	3	3	0.5	0.85	0.77

TABLE 6. (Continued)

Habitat	Year	S	N	N/V	H'	J'
Shrub Carr/Sedge Meadow						
Non-impacted	1973	23	214	5.1	2.39	0.76
	1974	23	378	7.3	2.12	0.68
	1975	17	180	6.2	2.21	0.78
	1976	24	270	6.4	2.25	0.71
Impacted	1973	27	251	6.0	2.20	0.67
	1974	18	176	5.5	2.30	0.79
	1975	15	167	4.9	2.03	0.75
	1976	20	180	4.3	1.78	0.59
Shrub Carr/Wet Mesic Forest						
Non-impacted	1973	8	19	3.8	1.75	0.84
	1974	8	11	2.8	1.97	0.95
	1975	6	8	2.7	1.73	0.89
	1976	13	25	3.6	2.42	0.94
Impacted	1973	4	8	1.3	1.39	1.00
	1974	8	30	7.5	1.78	0.85
	1975	7	21	4.2	1.68	0.86
	1976	4	23	3.8	0.64	0.46
Dry Forest/Old Field						
Non-impacted	1973	12	22	2.2	2.33	0.94
	1974	7	28	2.8	1.59	0.82
	1975	8	21	1.8	1.95	0.94
	1976	17	37	3.1	2.50	0.88
Impacted	1973	16	24	1.5	2.65	0.96
	1974	10	14	1.0	2.21	0.96
	1975	11	35	2.1	2.16	0.90
	1976	13	39	2.2	2.12	0.83

TABLE 7. PRESENCE OF SPECIES STUDIED (x)

Species	Sedge meadow	Wet forest	Dry forest	Old field	Shrub carr/sedge meadow	Shrub carr/wet forest	Dry forest/old field
Mallard (<i>Anas platyrhynchos</i>)	17	-	-	-	8.9	13	-
Blue-winged teal (<i>Anas diazona</i>)	15	-	-	-	14	13	-
Green heron (<i>Butorides virescens</i>)	7.5	3.9	-	-	7.1	-	-
American coot (<i>Fulica americana</i>)	5.0	-	-	-	-	-	-
Common snipe (<i>Capella gallinago</i>)	7.5	-	-	-	1.8	-	-
Mourning dove (<i>Zenaidura macroura</i>)	-	3.9	17	29	7.1	-	45
Downy woodpecker (<i>Dendrocopos pubescens</i>)	-	21	20	3.6	3.6	13	-
Red-headed woodpecker (<i>Melanerpes erythrocephalus</i>)	-	21	25	7.1	-	-	10
Common flicker (<i>Colaptes auratus</i>)	5.0	9.6	23	14	8.9	25	20
Crested flycatcher (<i>Myiarchus cinerascens</i>)	-	42	35	3.6	3.6	-	20
Eastern wood pewee (<i>Contopus virens</i>)	-	31	18	-	-	13	-
Blue jay (<i>Cyanocitta cristata</i>)	-	9.6	53	3.6	5.4	25	50
Brown-headed cowbird (<i>Molothrus ater</i>)	10	42	22	50	20	50	45
Red-winged blackbird (<i>Aegialius phoeniceus</i>)	75	25	25	43	96	75	40
Northern oriole (<i>Icterus galbula</i>)	2.5	11	17	7.1	1.8	13	15
Common grackle (<i>Quiscalus gutturalis</i>)	5.0	19	30	25	36	25	20
American goldfinch (<i>Spinus tristis</i>)	32	3.9	8	18	61	38	10
Song sparrow (<i>Melospiza melodia</i>)	45	71	22	25	84	100	30
Swamp sparrow (<i>Melospiza georgiana</i>)	40	-	-	-	71	13	-
Yellow warbler (<i>Dendroica petechia</i>)	10	1.9	3.3	-	29	-	5.0
Yellow-rumped warbler (<i>Dendroica coronata</i>)	-	-	1.7	-	-	-	-
Grey catbird (<i>Dumetella carolinensis</i>)	10	23	33	11	27	50	20
House wren (<i>Troglodytes aedon</i>)	-	37	23	-	-	13	15
Long-billed marsh wren (<i>Telmodytes palustris</i>)	20	-	-	-	23	-	-
White-breasted nuthatch (<i>Sitta carolinensis</i>)	2.5	44	30	3.6	-	-	5.0
Black-capped chickadee (<i>Parus atricapillus</i>)	-	29	17	11	-	-	25
American robin (<i>Turdus migratorius</i>)	7.5	27	35	18	32	63	40

stations examined in that habitat. Nine species were found in all habitats (33% of the total) and 2 species were found in only 1 habitat. The only ubiquitous bird in any of the habitats is the song sparrow, which occurred in all of the shrub carr/wet mesic forest stands.

Between-Habitat Ordination--

Of the 66 stations included in the ordination, 23 were physically impacted by construction activities and 43 were not impacted. Data for the non-impacted stations were ordinated initially to depict the compositional structure of the avian community in its "natural" state. Observations from each station in a given habitat were combined for each year so that a stand in the ordination represents the sum of all observations in that habitat for the June to July period of the years included.

Non-impacted Stands--The distribution of stands in the non-impacted ordination is given in Figure 6. Each habitat is represented by 4 stands, one for each sample year (1973 to 1976). In general, stands in the same habitat are clustered together. The bird compositional gradient reflects vegetation height on the first axis, ranging from low at the sedge meadow and shrub carr stands to high at the wet mesic and dry forest stands. Old field, dry forest/old field and shrub carr/wet mesic forest stands are intermediate in height and fall in the middle. The second axis reflects a range between pioneer communities e.g., old field and dry forest/old field habitats at the bottom, and more mature communities, e.g., forest and sedge meadow, along the top.

Many of the habitat plots in this ordination exhibit a cyclical pattern. Cycles are not uncommon in many animal species and may be stimulated by many factors. The period of observation (1973 to 1976) was characterized by weather extremes which may have contributed to the observed cycles. The years 1973 and 1976 were very dry in Wisconsin during June and July with 1976 considered an extreme drought. In contrast, 1974 and 1975 were somewhat better than usual for this period. These extreme weather conditions can affect water levels, insect distribution, seed production, etc., which, in turn, can affect avian population, resulting in population cycles.

The sedge meadow stands (1 to 4) and the shrub carr stands (17 to 20) are similar in this ordination. The two habitats have many species of plants in common so it is not surprising that the avian composition also is similar. Since all bird species present contribute to the position of each stand on an axis, results should not be attributed to only a few species. In some cases, however, dominant species can influence the ordination in an identifiable manner. For example, the location of stand No. 2 in the midst of the shrub carr stands, is probably due to the unexplained presence, during that year, of flickers (*Colaptes auratus*), brown-headed cowbirds (*Molothrus ater*), common grackles (*Quiscalus quiscula*), and robins (*Turdus migratorius*), species more associated with woody vegetation.

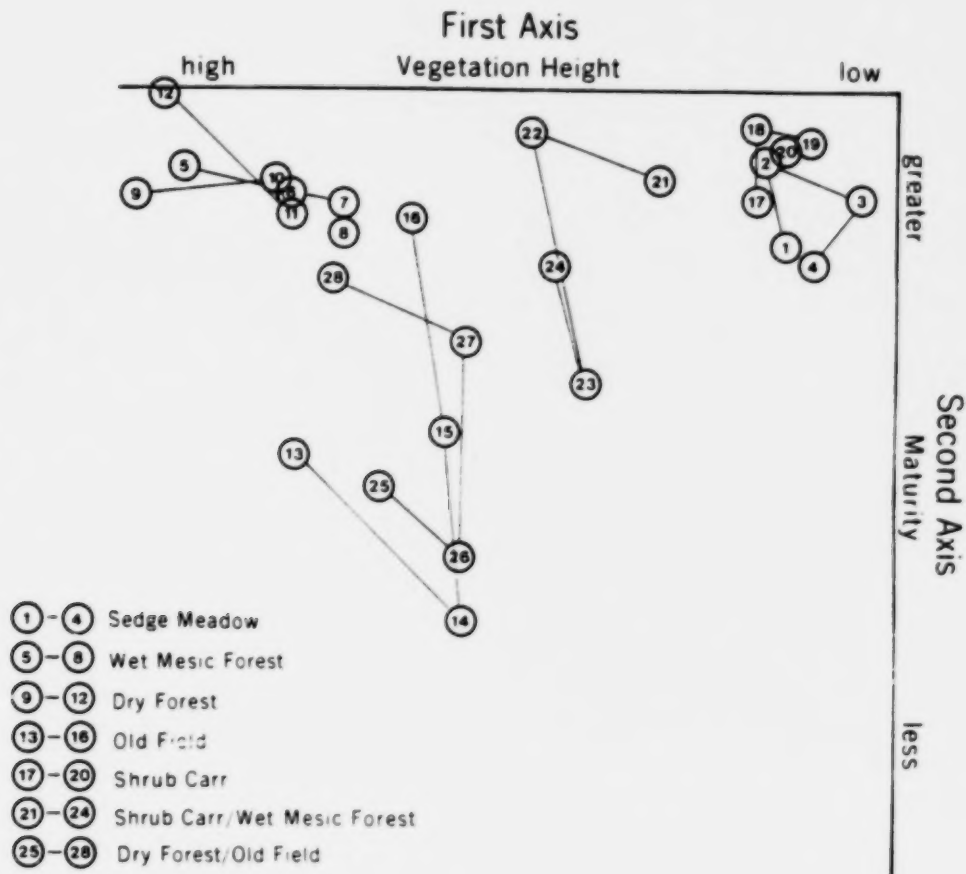


Figure 6. Polar ordination of non-impacted stands for all habitats. The bird compositional gradient reflects vegetation height on the first axis and vegetation maturity on the second axis. The four stands within each habitat represent the four sample years (1973-1976).

The old field (13 to 16) and old field/dry forest (25 to 28) stands are expectedly very similar. These stands, along with the shrub carr/wet mesic forest (21 to 24) stands show much more variability than the forest or sedge meadow stands, i.e., the distances between stands is greater. This may reflect an instability generally associated with early successional communities. The wet mesic forest (5 to 8) and dry forest (9 to 12) stands are more tightly clustered and have a good deal of overlap. The dry forest stands are in a characteristic cyclic pattern whereas the wet mesic forest stands are not. Stand 8 does not cycle back in the plot. Green herons (*Butorides striatus*), eastern wood pewees (*Contopus virens*), and song sparrows (*Melospiza melodia*) were among several species in greater abundance in stand 8 than in previous years. These species may have sought refuge in this stand during the extreme drought.

All Stands--A second between-habitat ordination was generated with the non-impacted and impacted stations, to show avian population response to impacts. Observations from the impacted and non-impacted stations in a given habitat were combined separately for each year so that a stand in the ordination represents the sum of all impacted or non-impacted station observations in that habitat for the June to July period of 1973 to 1976. The distribution of stands in the ordination for all stations is given in Figure 7.

The positions of the habitats in the plot and the axes delineations are much the same as those in the non-impacted ordination. One notable difference is that the distances between the impacted stations appear to be greater than the distances between the non-impacted stations. A Wilcoxon two-sample test confirmed that the interstand distances between the samples are significantly different at the 95% level of probability, with the impacted stations interstand distances greater. The greater distances mean that the impacted stations show greater variability and change to a greater extent from year to year than do the non-impacted stations.

Within-Habitat Ordination--

Stands in each habitat also were ordinated to provide greater resolution of changes which occurred in species composition and distribution during the study period. A stand in these within-habitat ordinations represents the sum of all visits to a given observation station within a habitat, for the June to July period of each year. Thus, each station is represented by 4 stands in the ordination plot, 1/yr. Stands with exactly the same species composition are superimposed upon each other in the plot, which accounts for dissimilar numbers of stands for each year.

Sedge Meadow Stands--The distribution of stands in the ordination of sedge meadow stations is given in Figure 8. The second axis differentiates between stands with a greater relative proportion of red-winged blackbirds and those with a greater proportion of swamp sparrow (*Melospiza*

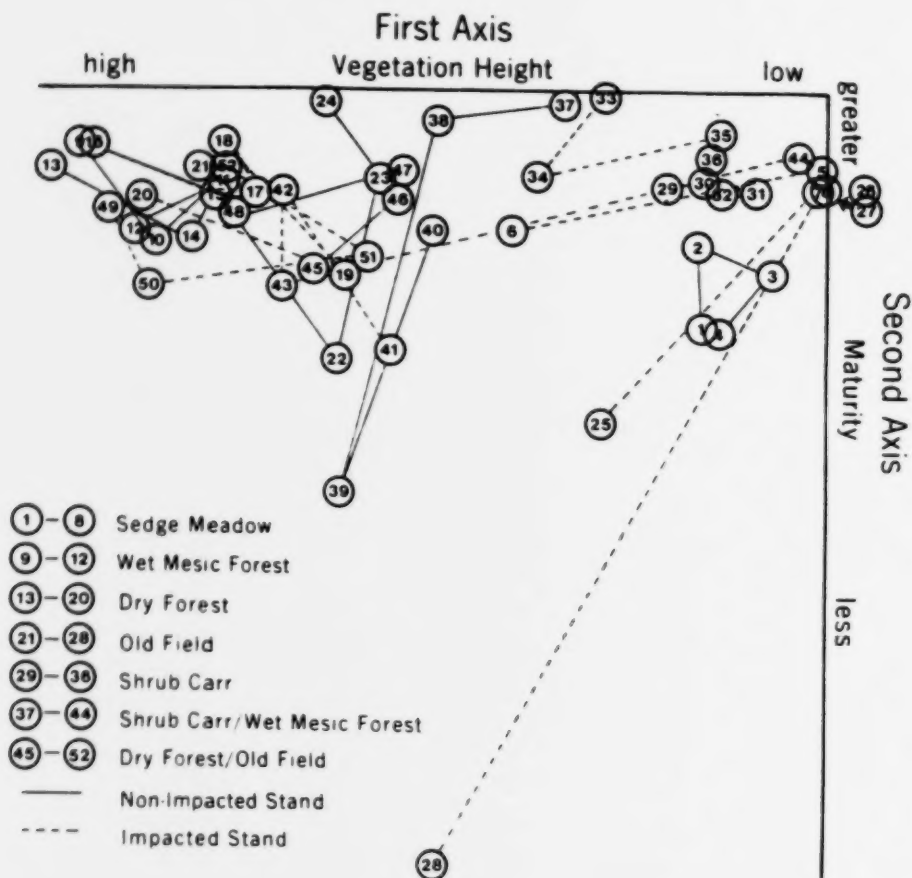


Figure 7. Polar ordination of all stands for all habitats. The bird compositional gradient reflects vegetation height on the first axis and vegetation maturity on the second axis. The eight stands per habitat represent non-updated stands over 4 years (1973 to 1976) and the impacted stands over the same 4 years.

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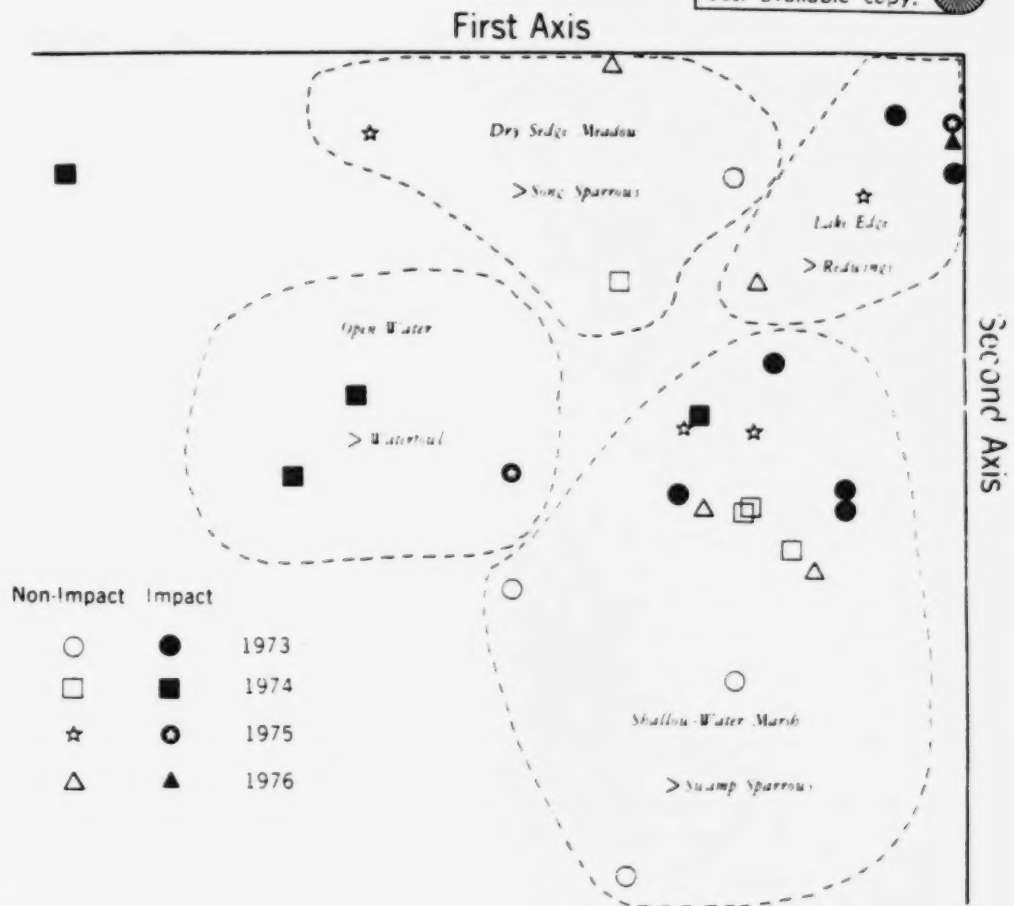


Figure 8. Polar ordination of sedge meadow stands. Seven impacted stands (one from 1979 and three each from 1975 and 1976) do not appear on the plot due to no species observed.

georgiana). This same characteristic is evident on many of the ordinations of other habitats as well (Figures 9 and 10). The first axis is not easily defined in this ordination. There is some pattern to the location of stands within the plot and this has been delineated to aid the reader. Four vegetation zones (dry sedge meadow, shallow water marsh, lakeshore edge, open water) in this habitat can be differentiated on the plot, each characterized by a greater relative proportion of a dominant species. The open water zone was formerly sedge meadow before being inundated by the cooling lake waters. Care should be exercised in interpreting the exact boundaries of these patterns since, as mentioned previously, the location of a stand is determined by all species rather than a few dominants and the delineated boundaries represent the author's interpretation of the data. However, the presence of a dominant species can cause a directional shift in a given stand.

No obvious pattern exists to differentiate between impacted and non-impacted stands or, between stands sampled during different years. It should be noted that a total of 7 stands (one from 1974 and three each from 1975 and 1976) do not appear on the plot because no birds were observed during the June-July study period for those years. With no data, the dissimilarity index value cannot be computed. The valueless stands are among those that were inundated when the cooling lake was filled, so the impact of this event is not fully represented by the ordination plot.

Wet Mesic Forest Stands--Nearly all of the wet mesic forest observation stations are located on Transect 1, at the far northern edge of the utilities' property. Because of this, there are no stands on the ordination plot which were impacted during the construction phase of the project. The ordination of the wet mesic forest stands is given in Figure 9. The stands are uniformly distributed between each axis with very little yearly pattern evident. The reason is the species of birds are rather uniformly distributed among the stands, and this creates little stand dissimilarity and thus shorter interstand distances. Also, no obvious dominant species exist among the wet mesic forest stands so it is difficult to label the areas. On the basis of this ordination, it would appear that the bird population of the wet mesic forest habitat was quite stable during the 4-yr of the study.

Dry Forest Stands--The ordination plot for the dry forest stands is illustrated in Figure 10. Two groupings of stands, one characterized by a greater proportion of blue jays (*Cyanocitta cristata*) and the other by a greater proportion of common grackles, can be distinguished in this plot. These stands have been encircled to aid the reader. To determine whether these species are independently distributed, a chi-square test of association was run. The test proved to be significant at the 95% level so the hypothesis of independent distribution was rejected. The observations suggest that blue jays and common grackles are negatively associated in the forest habitat. The reason for this is not clear but it may be due to competition or aggressive interaction between the two species, or to environmental factors. The habitats where these two species are most prevalent are only slightly different. The dry forested stands within the

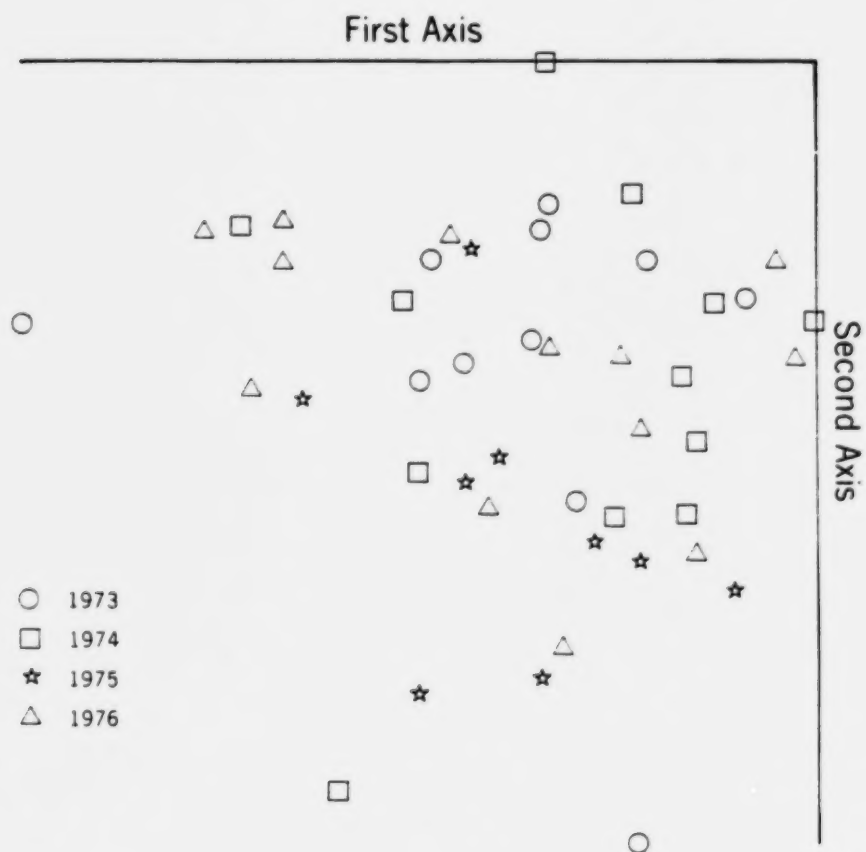


Figure 9. Polar ordination of wet mesic forest stands. Note: there were no wet mesic forest stands impacted by construction.

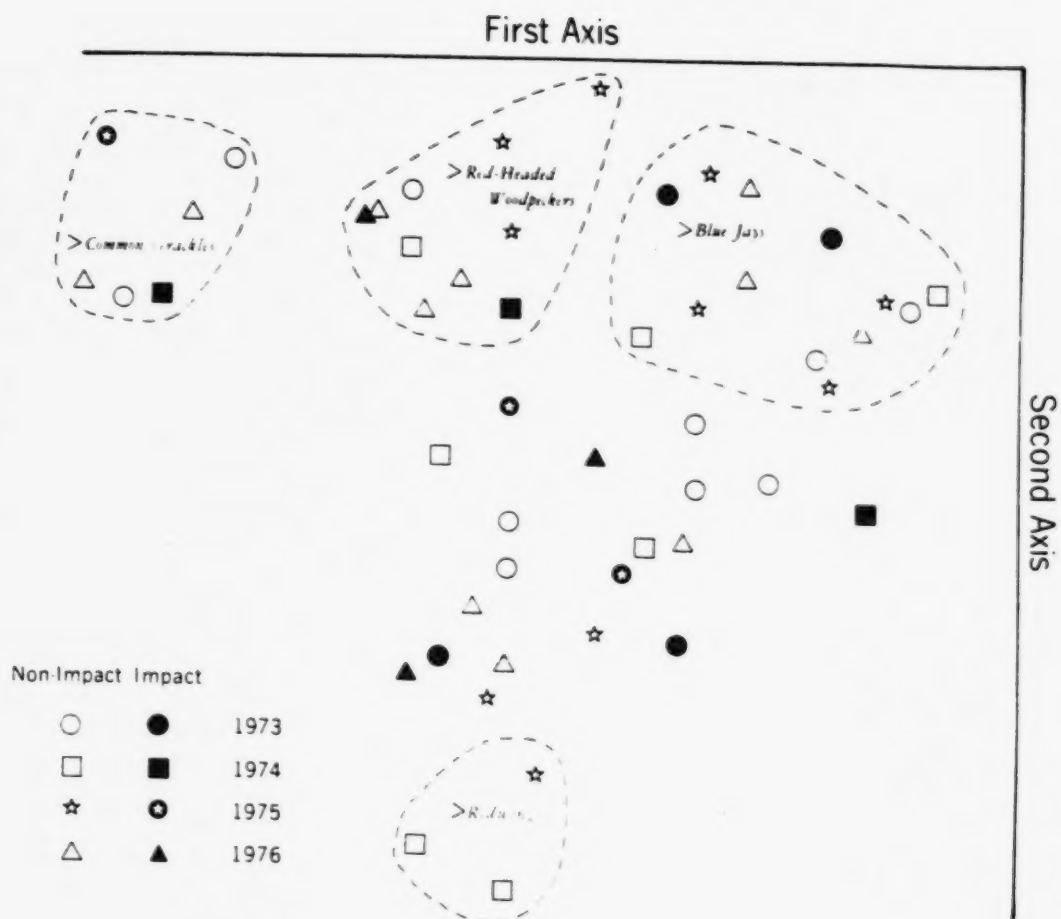


Figure 10. Polar ordination of dry forest stands. One impacted stand from 1974 is not plotted due to no species observed.

blue jay group are characterized by small openings in the canopy and the stands within the grackle group tend to border on wetland or open water areas. These local habitat differences may account for the observed distribution pattern.

Stands with a high proportion of red-headed woodpeckers (*Melanerpes erythrocephalus*) are grouped together at the upper margin of the dry forest plot. These stands share in common, a habitat characterized by mature trees with an open understory generally void of shrubs. A high proportion of red-winged blackbirds characterize several stands at the bottom of the plot.

Little additional pattern can be identified in the plot with respect to time or space. The interstand differences for a given stand with time are slightly greater in this habitat than in others. Although this may suggest greater variability, it more than likely reflects on the greater sensitivity of this particular plot. The dry forest stands are characterized by large numbers of different species but small numbers of individuals. Because of this, relatively small changes in the number of individuals observed can result in large changes in stand position, hence the greater interstand distances. The distances for the impacted stands are not significantly greater than those for the non-impacted stands.

Old Field Stands--The ordination plot of the old field stands is given in Figure 11. This plot is characterized by two groupings of species. The most distinct group has a high relative proportion of brown-headed cowbirds while the other group has a high relative proportion of red-winged blackbirds. These two species have the highest percentage presence of the species recorded in the old field stands and this dominance is reflected in the ordination plot.

Two stands in the old field habitat received major impacts during the construction phase of the project. Following the 1973 breeding season, the two stands were bulldozed for fill material and the bare ground was later re-seeded with a mixture of cover annuals and perennials. Following this impact, no species were observed during the 1974 and 1976 breeding seasons. The observation for 1975 was a lone red-winged blackbird. All three impacted stands which contained species are characterized by red-wings.

Some temporal variability is evident on the old field plot. Most of the stands with higher proportions of cowbirds were sampled during 1973 to 1975. The 1976 samples contained very few cowbirds.

Shrub Carr Stands--The distribution of stands in the ordination of shrub carr stands is given in Figure 12. The second axis again reflects a range between stands with a greater proportion of red-winged blackbirds and those with a greater song sparrow proportion. An examination of the stands themselves reveals that two environmental parameters largely are responsible for these gradients. A shrubiness gradient is reflected along the first axis with mean values ranging from 18 to 42% shrubs. A water depth gradient is reflected along the second axis.

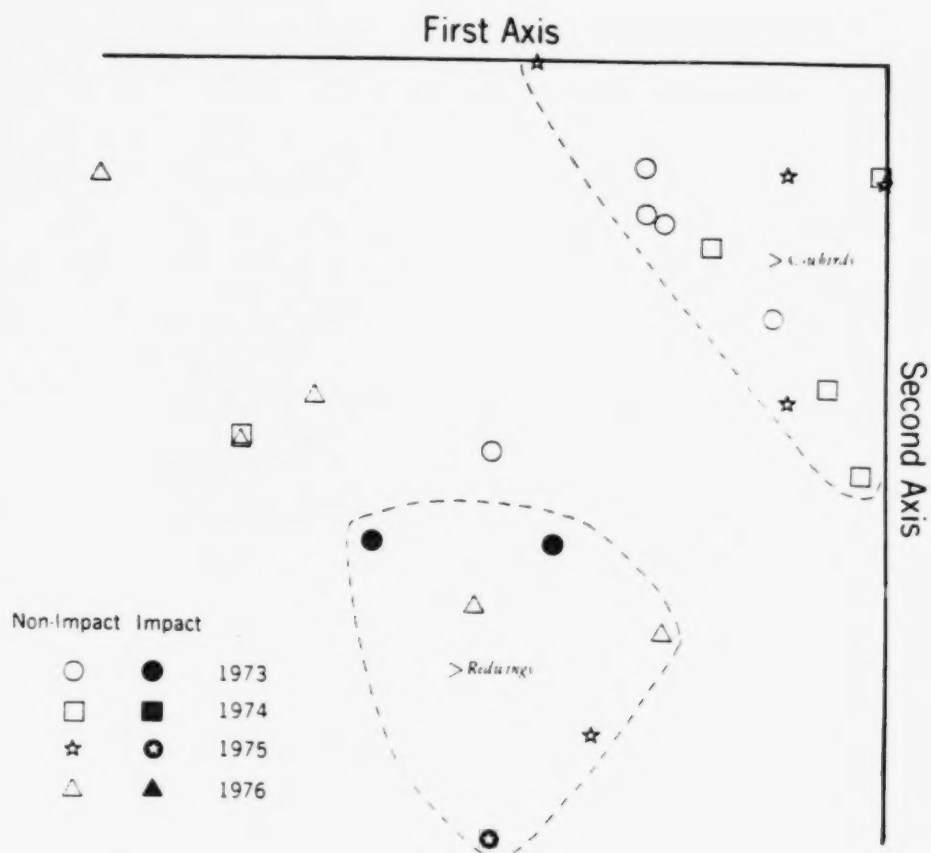


Figure 11. Polar ordination of old field stands. Five impacted stands (one from 1975 and two each from 1974 and 1976) are not plotted due to no species observed.

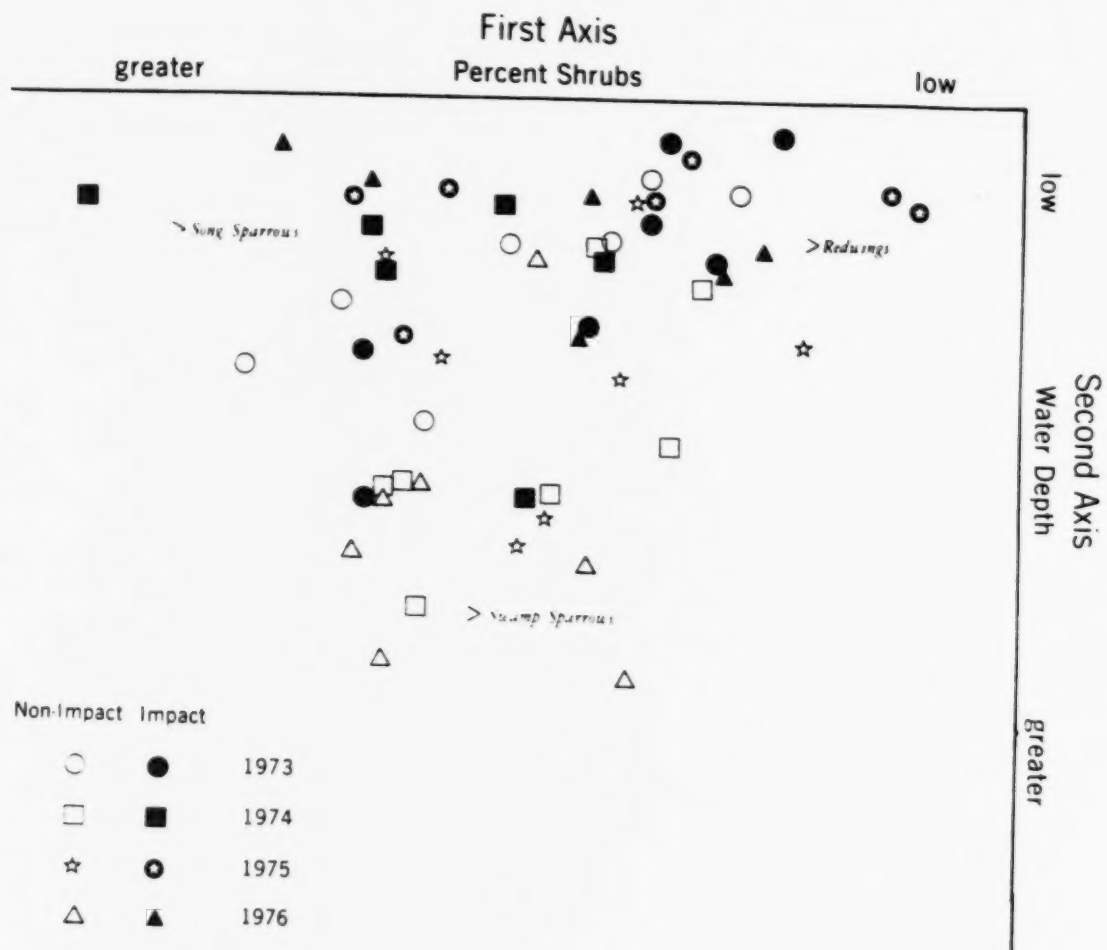


Figure 12. Polar ordination of shrub carr stands. Two impacted stands (one from 1974 and 1976) are not plotted due to no species observed. The bird compositional gradient reflects percent shrubs on the first axis and water depth on the second axis.

Although the three dominant bird species occur throughout most of the shrub carr stands, they are most prevalent relative to other species, in those stands where environmental conditions are most favorable for them. Song sparrows are most prevalent in areas with low water depth and high percentage shrubs; red-winged blackbirds are most prevalent where water depth is low and there are few shrubs; swamp sparrows are most prevalent where water depth is greater and there is an intermediate number of shrubs.

Shrub Carr/Wet Mesic Forest Stands--Figure 13 gives the ordination plot for the shrub carr/wet mesic forest stands. Only two stations in the transect sampling system are situated in this habitat so there are only 8 stands in the plot. It is difficult to describe any pattern in this plot probably due to the small sample size. As in several other ordinations, the stands on the right side are characterized by red-winged blackbirds.

Dry Forest/Old Field Stands--The ordination plot for the stands in the dry forest/old field habitat edge is given in Figure 14. Blue jays, morning doves, and red-winged blackbirds are the species with the highest percent presence in this habitat (Table 7). Blue jays are spread quite evenly among the stands but morning doves and redwings show prominence in two groups of stands that have been delineated on the plot. Although the stands are not spatially separated, the species characteristics are evident from the data.

There is little spatial or temporal pattern to the plot. The lack of spatial pattern may be due to an even species distribution among the stands or to comparison caused by the isolated position of the stand to the far left which is characterized by a high proportion of common grackles.

DISCUSSION

The results of the mean analysis show many cases where a specific construction activity was followed by an immediate decrease in the sample mean. Where the activity involved total destruction of a habitat, as in stations 201, 202, and 216, the sample mean remained depressed in the following years. Where construction resulted in only partial destruction of a habitat, as in stations 301, 306 and the transect 5 stations, the mean showed a tendency to rebound. Sample means for the stations inundated by the cooling lake (410 to 418) generally decreased except for when occasional rafts of waterfowl caused the mean to increase.

Variation about the mean was highest in the wetland stations of transects 1, 4, and 5 which are characterized by more gregarious species. In general, the large confidence intervals in most stations probably reflects the variable nature of bird observations rather than environmental factors.

Although diversity (H') is lower in the impacted stations for most habitats, the decrease is usually rather small. Of greater significance is the fact that diversity values generally decrease with time in the impacted

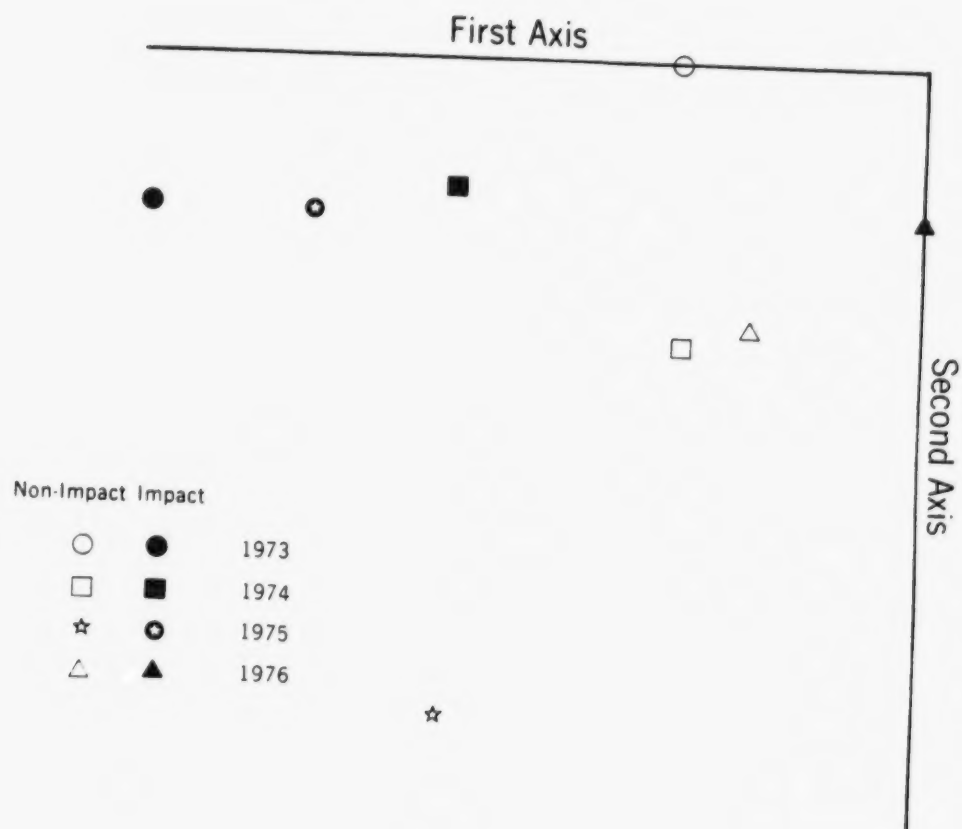


Figure 13. Polar ordination of shrub carr/wet mesic forest stands.

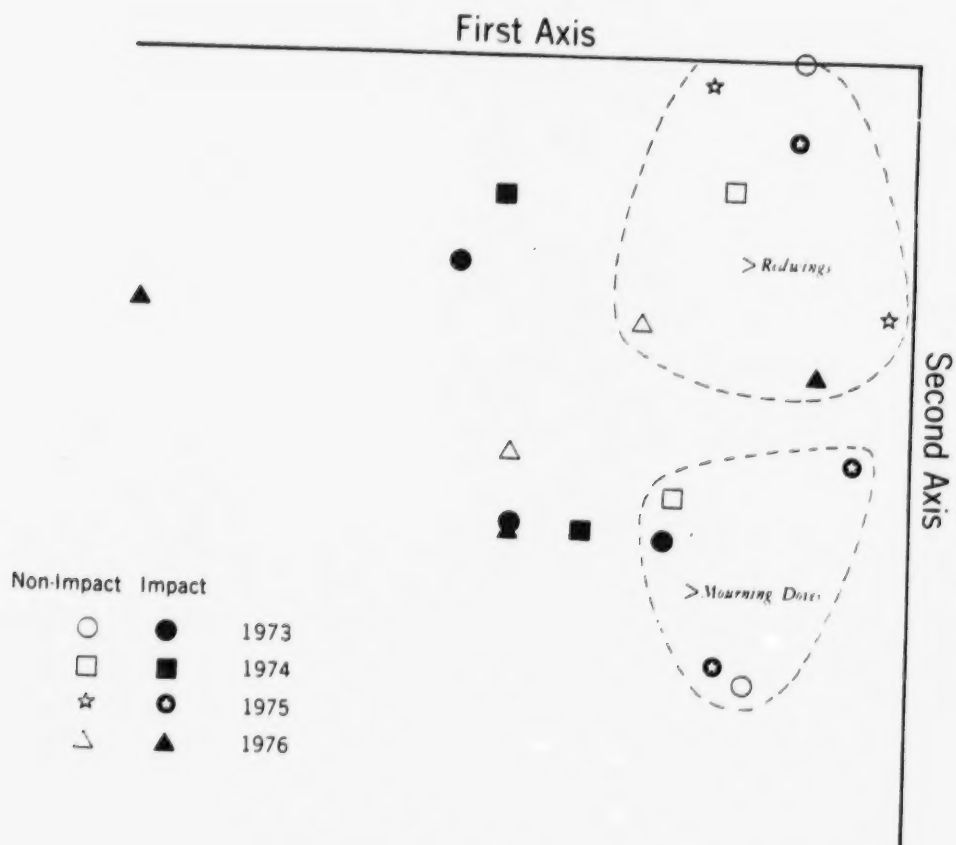


Figure 14. Polar ordination of dry forest/old field stands. One impacted stand from 1974 is not included due to no species observed.

stations (Table 6). Diversity in the nonimpacted stands does not exhibit this pattern. The drop in diversity is most evident in the impacted stations of the sedge meadow, where, following a peak in species diversity during lake filling, the values drop dramatically. A similarly large decrease occurs in the old field impacted stations (201 and 202). Whereas sample mean values for many stations have the tendency to bounce back following construction, diversity does not. This indicates that construction activities have a larger community level impact than is indicated by the species abundance changes alone.

Along these lines, it should be noted that the values of H' more closely follow the oscillations of species richness (S) than species abundance (N). For example, in the dry forest non-impacted stations, N declines with each year but H' follows the pattern of S . Tramer (1969) noted this same behavior in a number of breeding bird censuses and suggests that since birds are mostly "equilibrium" species, there is a tendency for the available species in most avian communities to partition the breeding space in a characteristic way. Because of this, a series of samples from the same or from different localities can yield similar distributions of species abundance. This lessens the weight of N in the calculation of avian diversity.

Of the seven habitats studied, diversity is lowest in the wetlands and old fields, and highest in the wet mesic and dry forests. Low foliage height diversity in the wetlands and old fields, where there are only one or possibly two vegetation layers, probably contributes to the decreased avian diversity in these habitats.

Evenness (J') values also are lower in the wetlands and old fields and higher in the forested habitats. A reason is many avian species in these habitats are gregarious and often polygamous. They defend only the immediate area around the nest against others of the same species and feed largely outside the nesting area (Nero 1956a,b; Weins 1965). This results in higher densities of the most abundant species and lower values of J' (Tramer 1969).

The higher values of J' in some of the less severely impacted stations are interesting. Construction activities in these stations did not completely eliminate the native vegetation, but altered some of the habitat characteristics. A species' habitat, within which it lives and reproduces, is composed of a complex matrix of environmental factors. As a species deviates from the optimal set of these factors it becomes less frequent. Species at the edge of this environmental gradient tend to be less tolerant to change because there is less buffering capacity to keep the environmental factors within the acceptable range. Habitat changes in some of the less severely impacted stations at the Columbia Site caused the less common species in those stations to disappear. This lowered diversity and, because only the most common species remained, evenness increased.

The influence of the most common species also is indicated on the ordination plots where groups of common species are evident in many of the habitats. Red-winged blackbirds, song sparrows and blue jays are among the species which frequently dominated the ordination plots, in nonimpacted and

impacted stands. Had the construction activities impacted these common species more greatly, the separation of impacted versus the nonimpacted stands would have been more evident. Instead, the influence of these relatively unaffected species overshadowed the effects that construction had on the rarer species.

In several areas where construction impacts were severe, no species were observed during the breeding season. The stands affected in this way could not be plotted using polar ordination.

The present study included only 2 yr of post-operational records. In this short period, however, a significant impact took place in the wetlands adjacent to the west dike of the cooling lake. With the filling of the cooling lake in 1974, substantial amounts of water began leaking under the dikes and into adjacent sedge meadow. This leakage increased the amount of water discharging into the sedge meadow by a factor of four, resulting in increased and more constant water levels, particularly during the summer months (Stephenson and Andrews 1976) (Figure 15). In addition, groundwater temperatures in the plant rooting zone in the area of the sedge meadow receiving most of the leakage (Figure 16) now range from 4°C in the summer to 21°C in the winter. The seasonal lag in temperatures is a function of distance from the cooling lake and the distribution of substrate materials.

These changes in the water regime have resulted in a number of major changes in the structure of the sedge meadow. Peat masses have floated up from the wetland bottom, flowing water has cut channels in the peat bed, and the warmer water causes more rapid oxidation of the peat. As a result, the effective depth of water in the sedge meadow has increased, especially in those areas immediately adjacent to the west dike of the cooling lake where many of the shrub carr observation stands are located. In addition, major changes were perceived in the wetland vegetation including significant alterations in shoot emergence patterns, extensive plant mortality, and shifts in community composition towards more annual and hydrophytic species (Willard et al. 1976).

The bird species composition in these altered areas of the wetland is also changing. Figure 17 illustrates the ordination plot for those shrub carr stands located along the cooling lake dike that were not impacted during the construction phase. These stands are, however, being affected by the leaking cooling lake water. The plot shows a trend for the stands to shift, with time, toward the bottom of the graph, or, toward deeper water conditions. These conditions favor the swamp sparrow which showed increased relative abundance in the 1976 stands. An ordination of shrub carr stands located to the east of the cooling lake does not show this trend (Figure 18). Further changes in bird species composition are likely should leakage continue to alter the water regime and wetland vegetation.

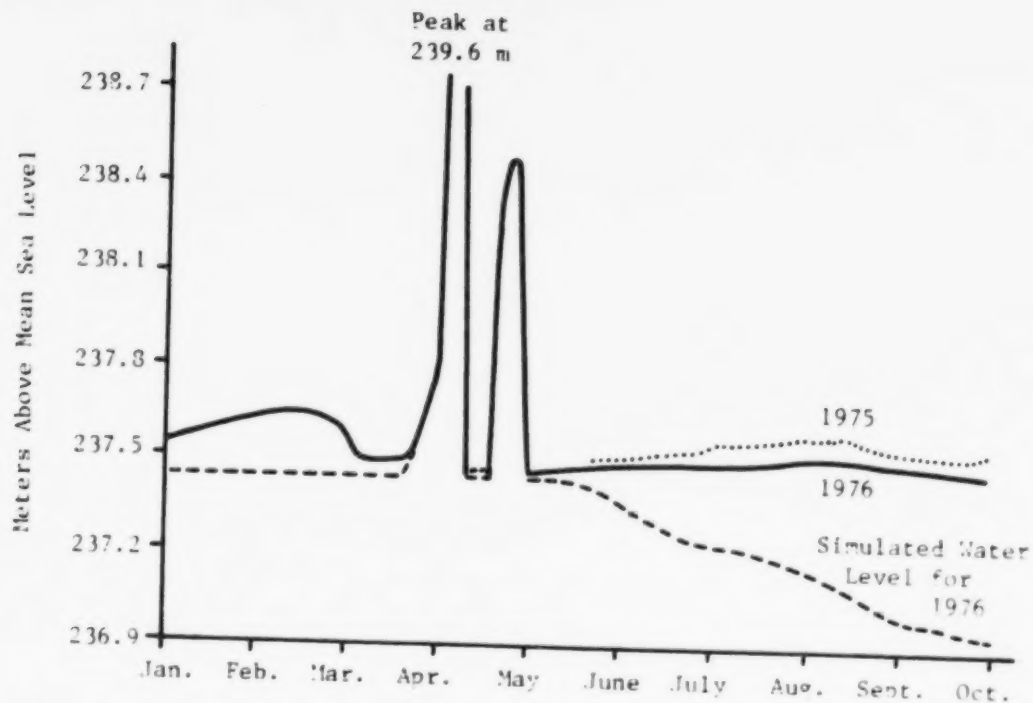


Figure 15. Typical water levels in the marsh west of the cooling lake during the summers of 1975 and 1976. The water level in the marsh without the presence of the cooling lake has been simulated. The two periods of high water in April 1976 were caused by flooding on the Wisconsin River. The sharp declines in water level after the flood suggests that the marsh has good internal drainage (from Anderson and Andrews 1976).

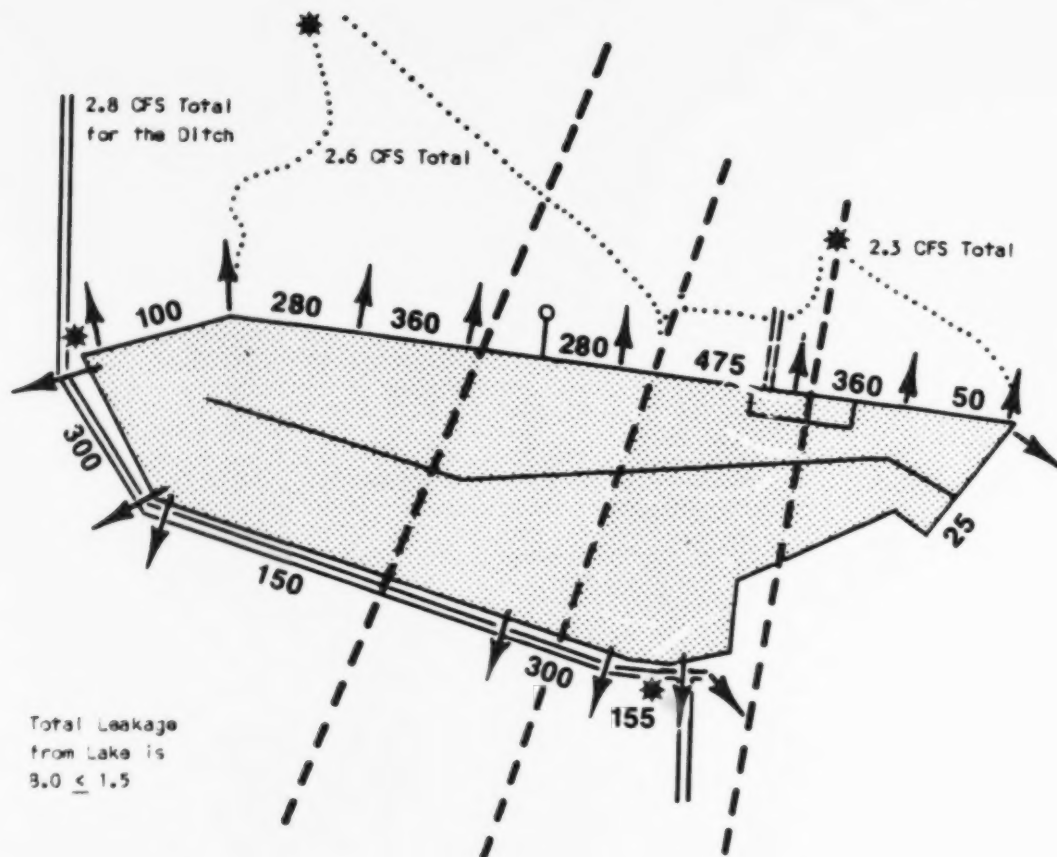


Figure 16. Estimated annual leakage rates from the cooling lake (gal./day/foot of dike). Surface water drainages in the sedge meadow are indicated by the dotted lines. (From Stephenson and Andrews 1976).

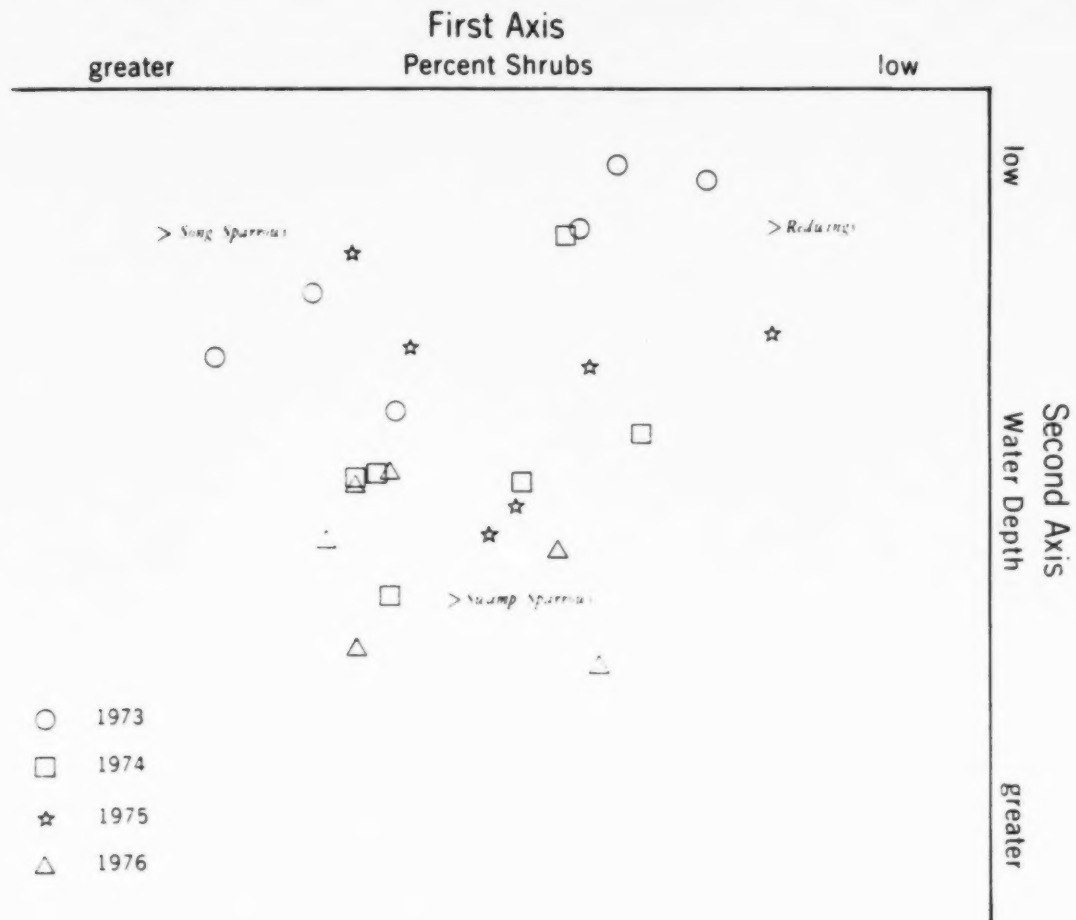


Figure 17. Polar ordination of non-impacted shrub carr stands in Transect 4. The bird compositional index reflects percent shrubs on the first axis and water depth on the second axis.

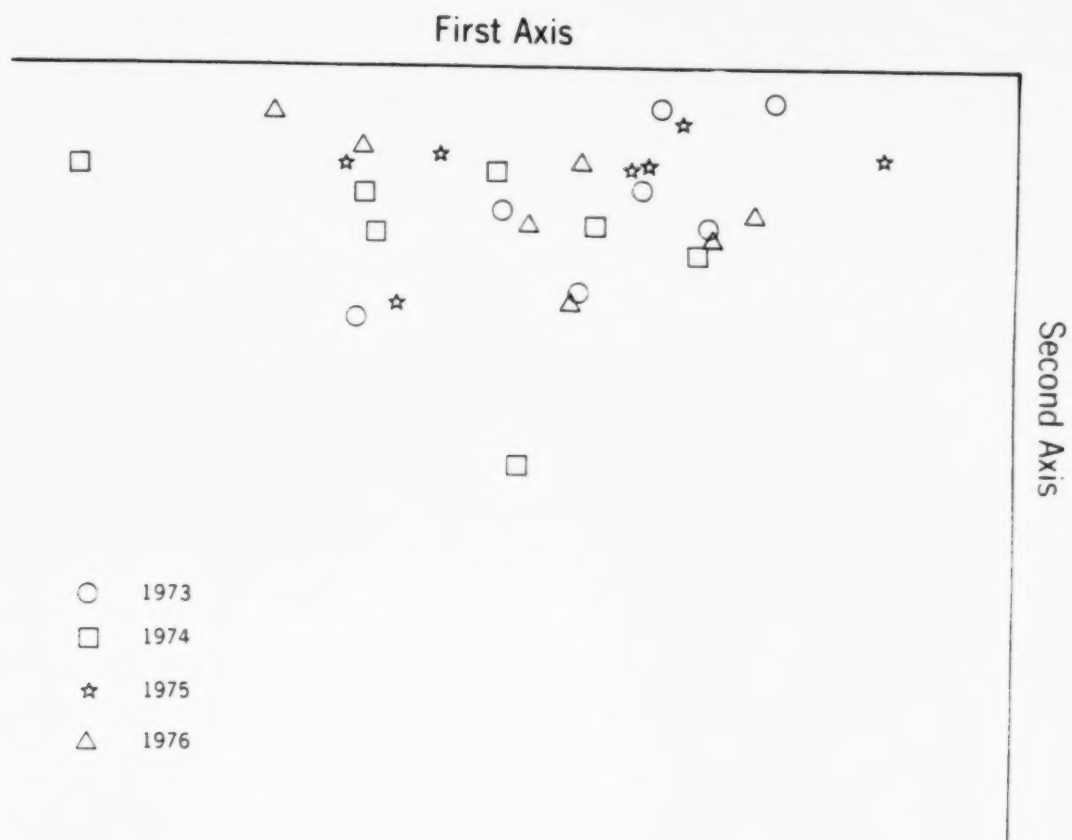


Figure 18. Polar ordination of shrub carr stands in Transect 5.

CONCLUSIONS

The construction of the Columbia Generating Station has had a number of impacts on the local bird community. These impacts have ranged from immediate responses to site-specific construction activities, to diversity and evenness changes within habitats, and to the alteration of overall bird community composition. The more common species appear to be least affected by construction activities, which only temporarily displaced them. The rarer species have been more permanently affected and this has altered species diversity and evenness values. The proliferation of common species at the expense of rarer ones also can have serious implications concerning community productivity, stability, and succession.

It may be too early to detect most post-operational impacts associated with the plant. However, leakage of cooling lake water is one such impact that is having an immediate and significant impact on 450 ha of wetlands to the west of the cooling lake. Additional changes in bird species composition is expected if leakage continues to alter the water regime and wetland vegetation. Polar ordination has been a useful tool in describing the composition and distribution of wetland bird species as they relate to percentage of shrubs and water depth. Further use of this technique is possible in predicting how manipulation of these parameters affect additional changes in wetland bird populations.

In the remaining habitats, the most common species tended to mask the rarer species in the ordination plots. In order to detect compositional changes in the rarer species, some modification of the polar ordination technique would be necessary. Relativizing the data to the number of samples rather than the number of individuals could allow for greater resolution of the rarer species.

SECTION 5

CHANGES TO GREAT BLUE HERONS

INTRODUCTION

The great blue heron (*Ardea herodias*) is the largest and most widely distributed of the American herons. It is a sociable species preferring to nest in dense colonies, ranging in size from a few to several hundred pairs. Where trees are available they select the tallest in which to build their nests. The location of the nesting rookery depends more on the available food supply for the young than on the presence of suitable trees. However, since security of eggs and young is the main objective, a remote, relatively inaccessible locality is chosen (Bent 1963).

Great blue herons exhibit variation in sociability in feeding behavior as well as in nesting. In a study of a coastal rookery in British Columbia, Krebs (1974) observed that when food was present in large undefendable, shifting clumps, herons foraged in groups; when food resources were either widely scattered and/or easily defendable, foraging herons were solitary. This type of social modification also has been observed in other species (Zahavi 1971).

The modification of feeding and nesting behavior in great blue herons is considered as it relates to impacts caused by construction of a large, coal-fired electrical generating station.

METHODS

A great blue heron nesting colony located in the Wisconsin River flood plain near Long Lake, approximately 6 km south of Portage, Wisconsin, was studied from 1974 to 1977. The colony is situated in an isolated and dense stand of southern lowland forest dominated by silver maple (*Acer saccharinum*), river birch (*Betula nigra*), and American elm (*Ulmus americana*). The numbers and distribution of nests in the colony were counted and mapped after the leaves had fallen, which made the nests more conspicuous. Only active nests were included.

In addition to the nest data, observations were made of heron behavior on their feeding grounds. An important feeding site for the herons was the 400 ha wetlands complex located 2 km to the east of the nesting colony

(Figure 19). These wetlands are composed primarily of sedge meadow and shallow water marsh.

DATA AND RESULTS

During 1971 and 1972, dikes were constructed around a 200 ha portion of the wetlands to create a cooling lake for the adjacent generating station. Herons continued to forage in the diked area in groups of up to 12 individuals until the dikes were joined and the lake was filled with water to a depth of 3 m during the winter of 1974. Few herons were observed foraging on the site during the summer of 1975, apparently in response to the abrupt change in the feeding habitat and renewed construction activity around the lake.

In 1976, herons began foraging along the west dike and the western edge of the center dike of the cooling lake. This section of the lake has the coolest water and contains an abundant population of aquatic invertebrates and fish (Kitchell 1976). The herons no longer foraged in groups, but rather, fed individually along the dikes at intervals of approximately 150 m. These feeding distances were regularly maintained and when an individual was flushed from its feeding site, it quickly returned to the same site. As many as 19 great blue herons fed along the dikes in this manner at any one time. Due to the deep water and the steep slopes of the dikes, the herons were unable to wade >0.5 m out into the water.

During this period, the number of nests in the Long Lake Colony decreased from 113 in 1974 to 16 in 1977 (Figure 20). The nesting site remained essentially unchanged, and with the exception of one windfall, there have been no observable physical changes.

DISCUSSION

The effects of human activities on great blue heron colonies have received some attention in the literature. Pearson (1936) reports that unless the herons are "seriously molested," they are likely to return to the same nesting site for many successive years. In Oregon, logging activity 0.5 km distant was observed to adversely affect a heron nesting colony, although some active nests were still present within 219 m of the disturbance (Werchkul et al. 1976). In the Oregon study, colony size density and nest occupancy decreased in the disturbed sites. Nest densities averaged 94 active nests/ha in disturbed sites and 259 in undisturbed sites.

In the present study, construction activities at the Columbia site were 1.5 km from the Long Lake nesting colony. Nest density in 1974 was 94 active nests/ha which compares favorably to the mean found in disturbed colonies in the Oregon study. It is not known to what extent this figure reflects possible construction impacts prior to 1974. However after the cooling lake was filled in 1974, nest density dropped to 69 in 1975, 33 in

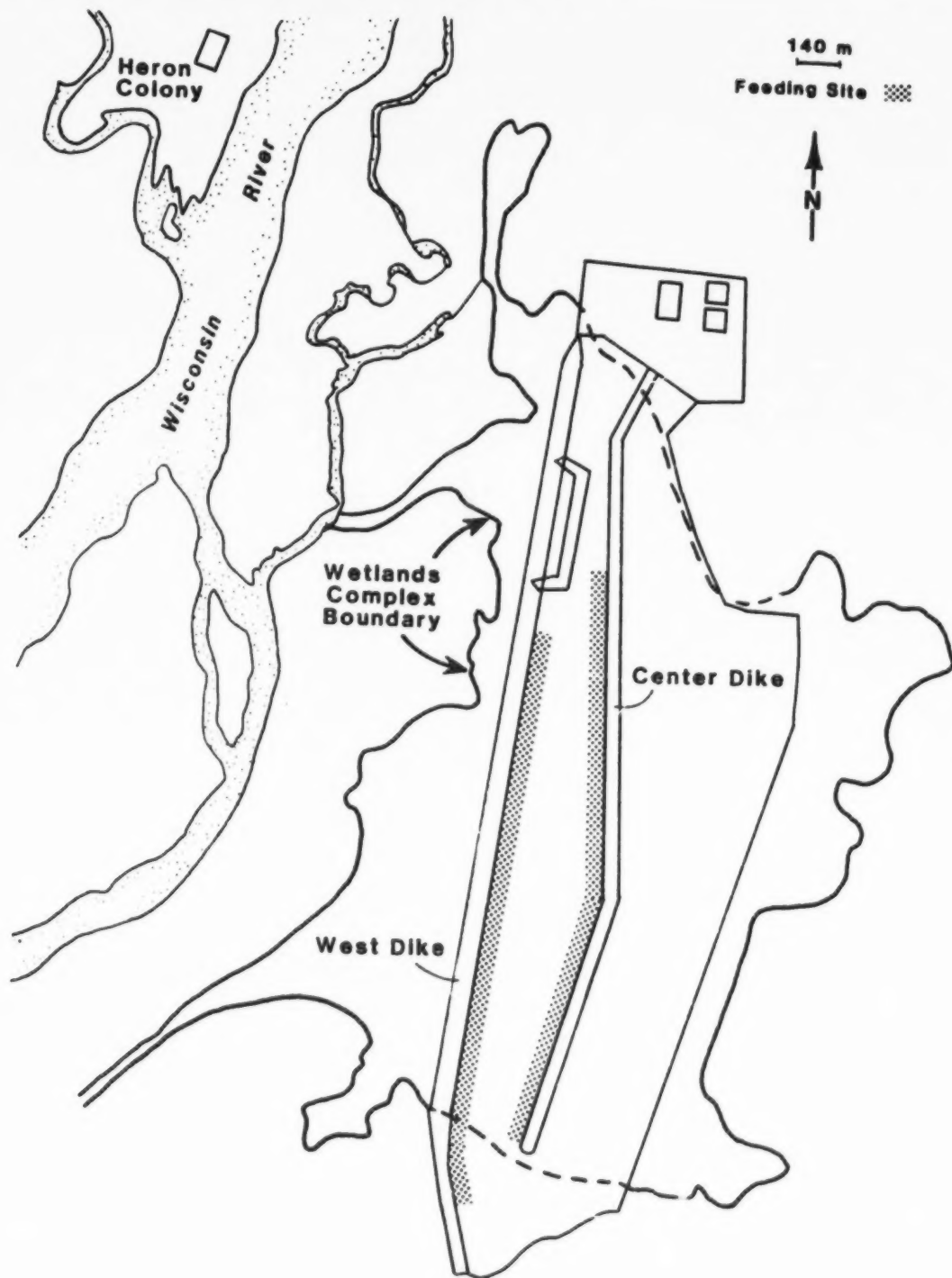


Figure 19. Great blue heron study area.

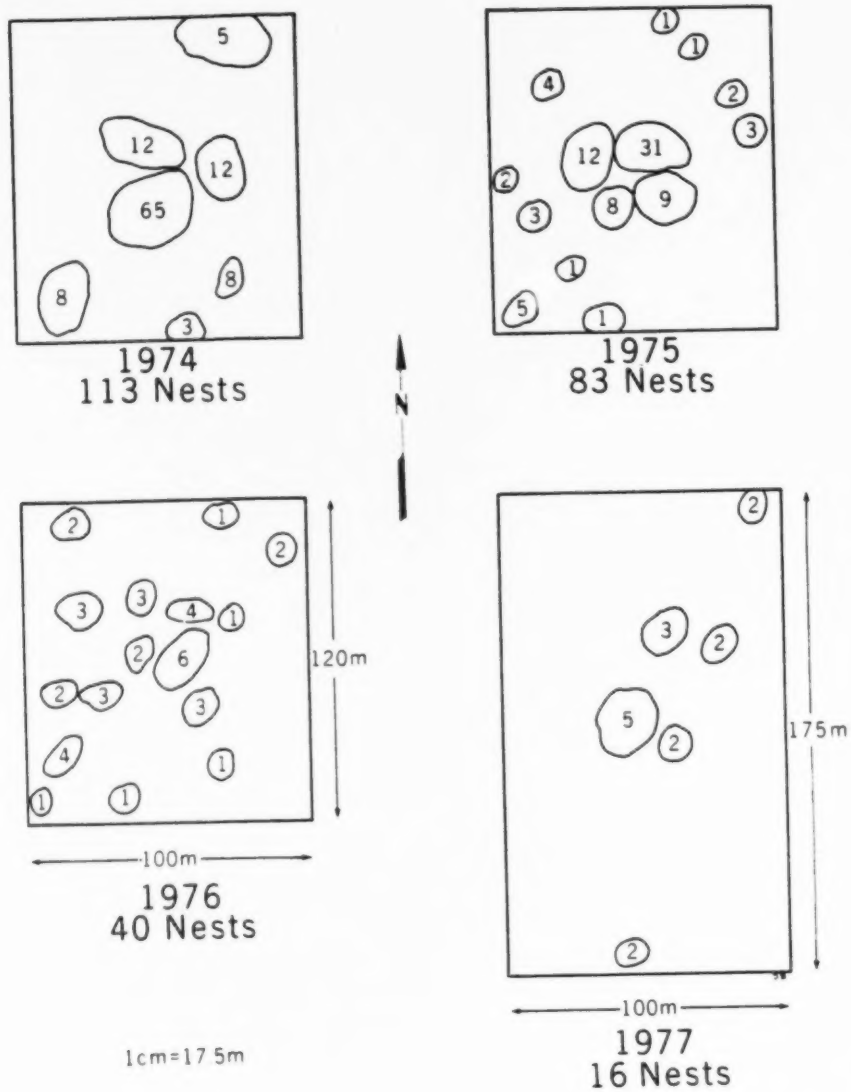


Figure 20. Generalized distribution of nests in the Long Lake Great Blue Heron Rookery.

1976, and 9/ha in 1977. It seems likely that the inundation of the heron's feeding grounds in the cooling lake contributed to this sharp decline in active nests.

Despite the productivity of the lake, most of it is unavailable to the herons since foraging is possible only along the lakeshore. This limited availability of food is made evident by the large feeding distances maintained by the foraging herons. This feeding behavior is in sharp contrast to that observed prior to the lake filling.

CONCLUSIONS

The Columbia Generating Station has impacted the nesting colony of great blue herons at Long Lake primarily by limiting the availability of food due to the construction of a 200 ha cooling lake. The construction has restricted the number of foraging sites to the extent that the habitat can no longer support the large population of herons which formerly fed there. This and possibly other disturbances at the Columbia Site have directly contributed to the subsequent decline in the nesting heron population.

SECTION 6

DRIFT FENCE-PITFALL TRAPPING FOR COLLECTING BASELINE DATA ON SMALL ANIMAL POPULATIONS

INTRODUCTION

An additional objective of the Columbia Project was to develop methods to predict environmental impacts in similar situations using a minimum of baseline studies (Terrell et al. 1978). Small mammals, amphibians, and reptiles were an essential component of the study. They occupy a variety of positions in food webs and may reflect environmental changes in a different manner from either primary producers or more mobile species, such as birds or deer.

Collecting baseline data involves many problems. The size and secretive or nocturnal nature of small animals makes direct field observation impractical for qualitative data collection; indirect methods are thus required. These include various live traps, snap traps, sand transects, smoked paper, biotelemetry, dropping boards, photographic recorders and other ingenious techniques. Environmental scientists need to compare (and to improve upon) current field methods (Delany 1974), particularly regarding costs and relative trapping (i.e. presence and abundance). For example, Briese and Smith (1974) compared the use of a drift fence and pitfall traps with drop door live trapping on a grid. They found pitfall traps captured a greater diversity of small mammals and were more effective in capturing shrews.

The location and time of sampling affect trapping results (Willard 1978). Species may exploit changing habitats at different times. This timing may fluctuate regularly (e.g. hourly, daily or seasonally) or irregularly. Total populations fluctuate seasonally and yearly. This natural variability of small animal populations necessitates large samples with time to obtain reliable population estimates.

This section examines the utility of drift fence-pitfall trapping in collecting baseline information. It discusses problems of timing, spatial location and influence of weather factors on the movement of small animals. Numerous experiments concerning the effects of abiotic factors on animal activity have been conducted on captive animals under controlled conditions. These environmental relationships are more difficult to study in uncontrolled field conditions, but the results are ultimately of greater ecological significance (Platt et al. 1964).

METHODS

Study Area

The field study was conducted at the Columbia Generating Station located on the flood plain of the Wisconsin River in southern Wisconsin. Sampling took place between the recently-constructed cooling lake and the Wisconsin River.

Weather Data

Local climatological data were obtained from the Truax Field-National Weather Service Station, Madison, Wisconsin (43° 08'N, 89° 20'W), located approximately 48 km south of the study area. Precipitation data were obtained from hourly totals. Other weather parameters are daily means and were calculated from meteorological observations gathered at 3-hr intervals. A simple rain gauge at the site coupled with field observations indicated that precipitation periods at the site were roughly simultaneous with those observed at Truax Field. However, we could not correlate the absolute values for any measure. We can use the weather trends with confidence.

Field Methods

Drift fences were constructed of aluminum sheeting or screening approximately 15 m long and 30 cm high with an additional 10 cm buried in the ground to prevent animals from burrowing under the fence. Pitfall traps were of three types: 1. 5 gal plastic buckets 30 cm in diameter and 40 cm deep; 2. 3 lb metal coffee cans 15 cm in diameter and 25 cm deep; and 3. 2 x 3 lb metal coffee cans placed end to end (with both ends removed from the upper can) 15 cm in diameter and 50 cm deep. Pitfall traps were buried symmetrically on each side of, and adjacent to, the fence with the top of the bucket at ground level (Figure 22). Traps were emptied every other day beginning June 11 and ending October 31, 1976. All traps were covered on August 14 and reopened on August 24. Captured animals were released on the opposite side of the fence from which they were captured.

Drift fences were arranged on ecotones between wet and dry communities including submergent aquatics, sedge meadow, woodland pond, lowland hardwood forest, old field and sand blowout (Figure 21). Drift fences were oriented: 1. parallel to habitat boundaries, 2. perpendicular to habitat boundaries, and 3. a combination of these drift fence types in an "L" or "T" formation. Trap orientation allowed us to distinguish whether animals were moving between habitats or from a wet area to a dry area. Animals captured using parallel fences can be subdivided into two categories--wet and dry. The side of the fence facing the wetter habitat is called wet and the other side

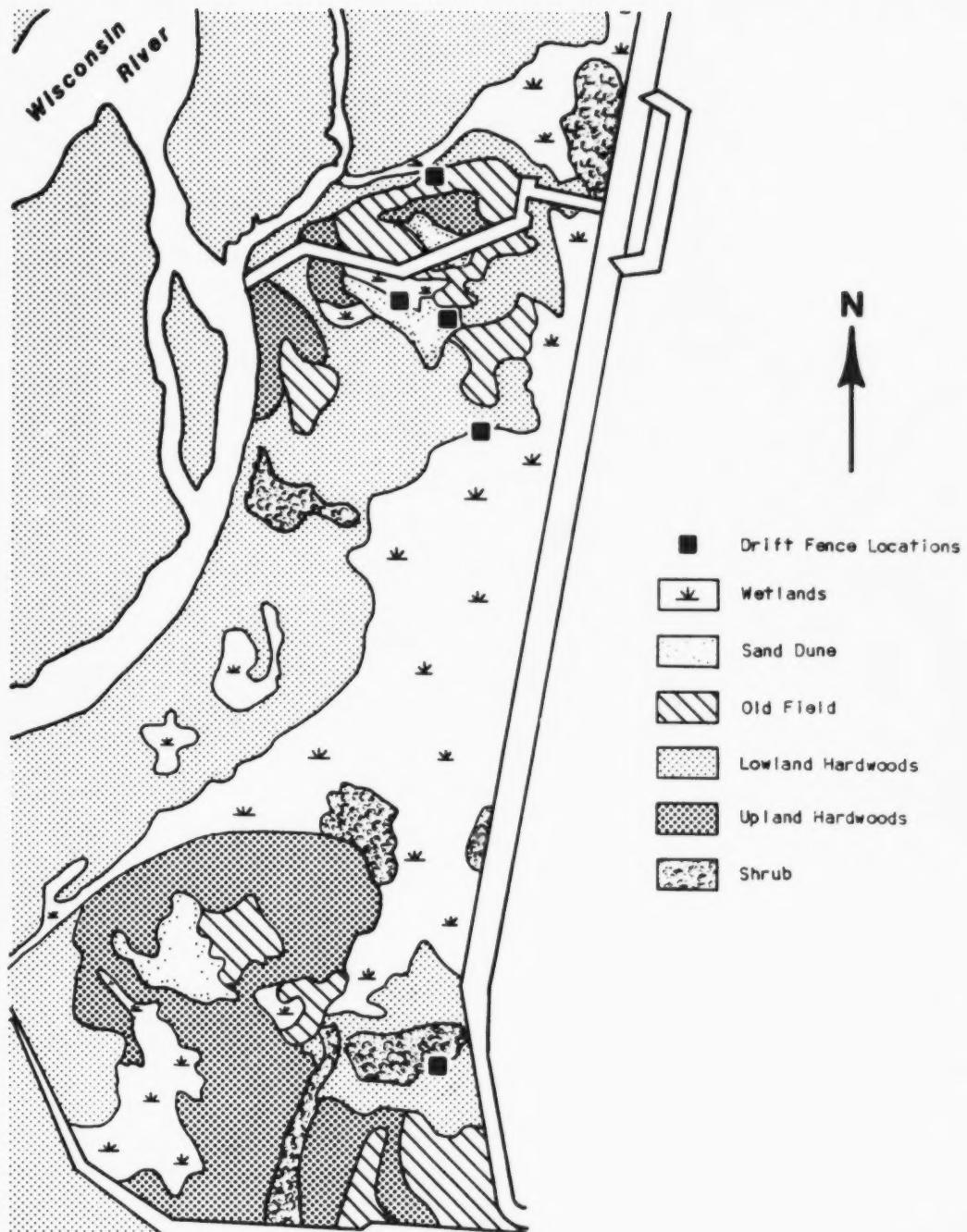


Figure 21. Drift fence trapping locations.

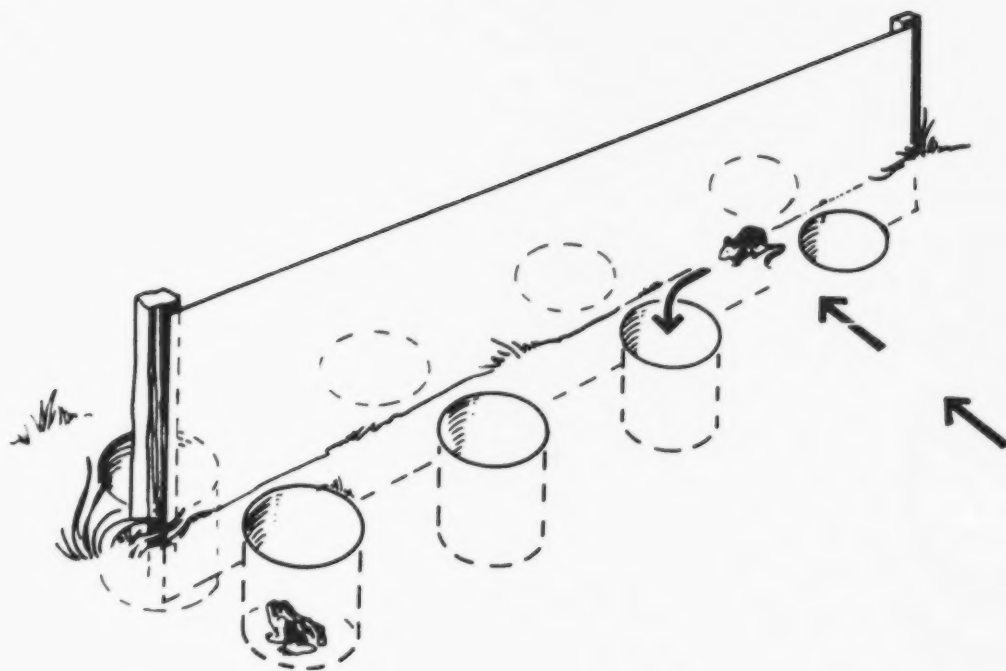


Figure 22. Drift fence with pitfall traps.

dry. Five groups of animal captures are discussed, namely, total, perpendicular, parallel, wet side and dry side.

Statistical Methods

Statistical methods are from Sokal and Rohlf (1969) except for the analysis of covariance taken from Steel and Torrie (1960). Parametric and non-parametric tests were used with a rejection level of $\alpha = 0.05$. the assumption of independently distributed errors necessary for parametric statistical analysis is questionable, as in most field experiments. However, autocorrelation between adjacent values (Box 1976) is not significant.

RESULTS

Some 1,227 individuals of 28 species of small mammals, reptiles and amphibians were captured in pitfall traps (Table 8). The composition of these captures varied with time and space, with some animals being captured throughout the study, while others were captured discontinuously. Presented below are detailed results for the most common animal, the cinereus shrew (*Sorex cinereus*), followed by some general results for other animals.

Sorex

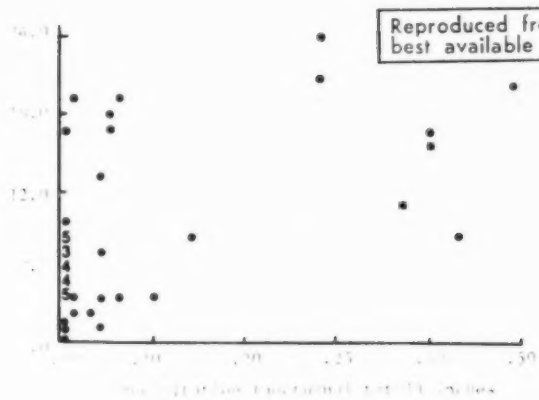
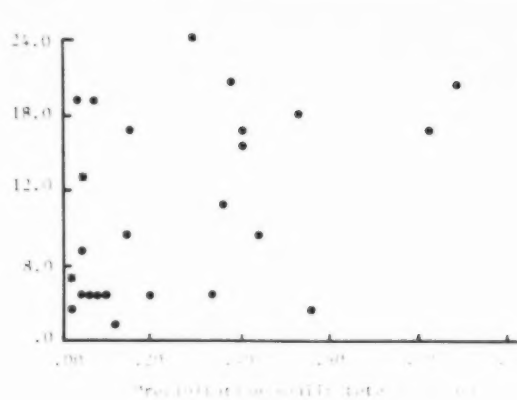
This animal group is composed of primarily *S. cinereus* and a small number of the saddle-backed shrew (*S. laricorum*). Perpendicular, parallel, wet and dry *Sorex* captures fit a Poisson distribution ($p \leq 0.05$); total *Sorex* captures do not. Numerous transformations to normalize the data were tried and an $(x + 0.5)$ transformation produced the best fit for all five groups ($p \leq 0.05$).

Several statistical tests were performed on *Sorex* numbers to determine if a difference existed in trap captures as a function of wet versus dry sides of fences. Two non-parametric tests were run; a Sign Test indicated no difference, but a more powerful Wilcoxon Rank Test suggested a difference was present ($p \leq 0.05$). A paired t test, a parametric test, also indicated a difference was present ($p \leq 0.05$).

Figure 23 contains graphs of total *Sorex* trap captures against 10 weather parameters. Most show a general positive relationship while some (e.g. relative humidity) exhibit an initial positive relationship followed by a negative relationship. Correlation analysis (Table 9) indicates that precipitation, cloud cover, dew point and temperature are positively associated with shrew numbers and that these weather factors are interrelated. To construct a predictive model of *Sorex* numbers, regression analysis and analysis of variance were explored. However, an analysis of covariance (ANCOVA) seemed more appropriate because it combines the ideas of analysis

TABLE 8. SUMMARY OF PITFALL TRAP CAPTURES OF SMALL MAMMALS, REPTILES, AND AMPHIBIANS

Mammals	No.	Reptiles	No.	Amphibians	No.
<i>Sorex arcticus</i> Saddlebacked shrew	446	<i>Ophiomorus attenuatus</i> Western glass lizard	3	<i>Bufo americanus</i> American toad	124
<i>S. cinereus</i> Cinereous shrew		<i>Storeria dekayi</i> Dekay's snake	34	<i>Rana ciamitana</i> Green frog	52
<i>Blarina brevicauda</i> Short tailed shrew	12	<i>S. occipitomaclata</i> Red bellied snake	82	<i>R. pipiens</i> Leopard frog	185
<i>Microtus pennsylvanicus</i> Meadow vole	79	<i>Thamnophis sirtalis</i> Eastern garter snake	54	<i>R. sylvatica</i> Wood frog	2
<i>M. ochrogaster</i> Prairie vole		<i>Opheodrys vernalis</i> Smooth green snake	25	<i>Pseudacris triseriata</i> Chorus frog	3
<i>Zapus hudsonius</i> Hudsonian jumping mouse	44	<i>Heterodon platyphonus</i> Eastern hognose snake	6	<i>Hyla crucifer</i> Spring peeper	83
<i>Peromyscus bairdii</i> Prairie deer mouse	9	<i>Chrysemys picta</i> Painted turtle	20	<i>H. versicolor</i> Grey tree frog	8
<i>P. gracilis</i> Woodland deer mouse		<i>Emydoidea blandingi</i> Blanding's turtle	7	<i>Ambystoma laterale</i> Blue spotted salamander	23
<i>Eutamias jacksoni</i> Wisconsin least chipmunk	1	<i>Graptemys geographica</i> Map turtle	2	<i>A. tigrinum</i> Tiger salamander	2
		<i>Trionyx spiniferus</i> Spiny soft shell turtle	1		



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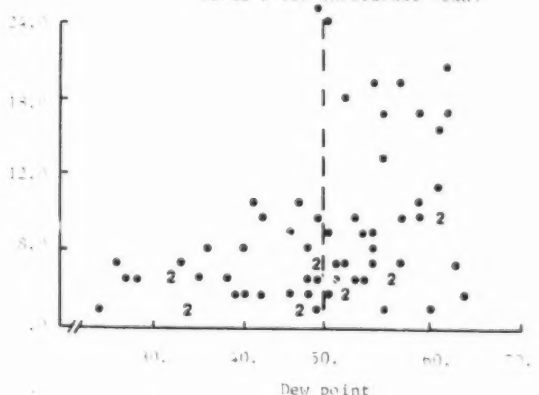
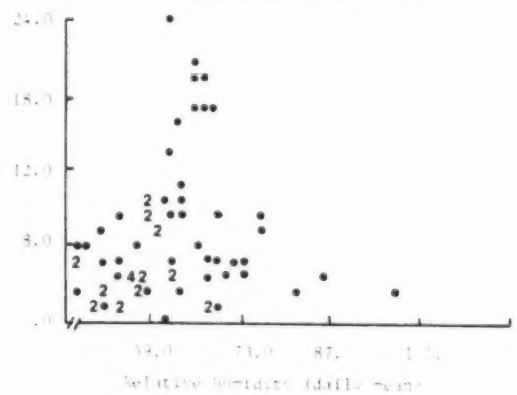
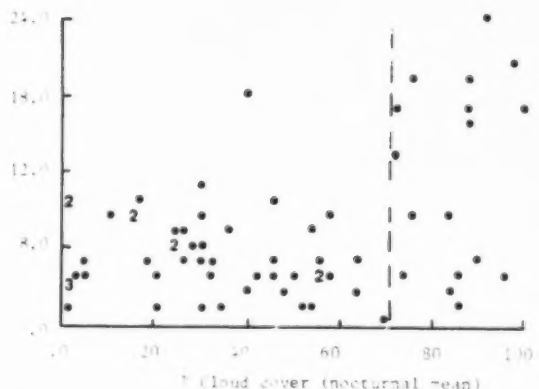
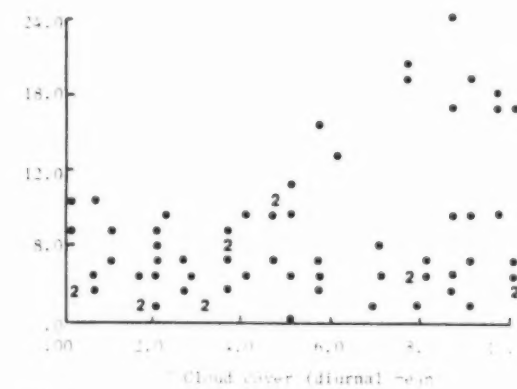


Figure 23. Number of *Sorex* captures as a function of weather conditions.
(Figure 23, continued.)

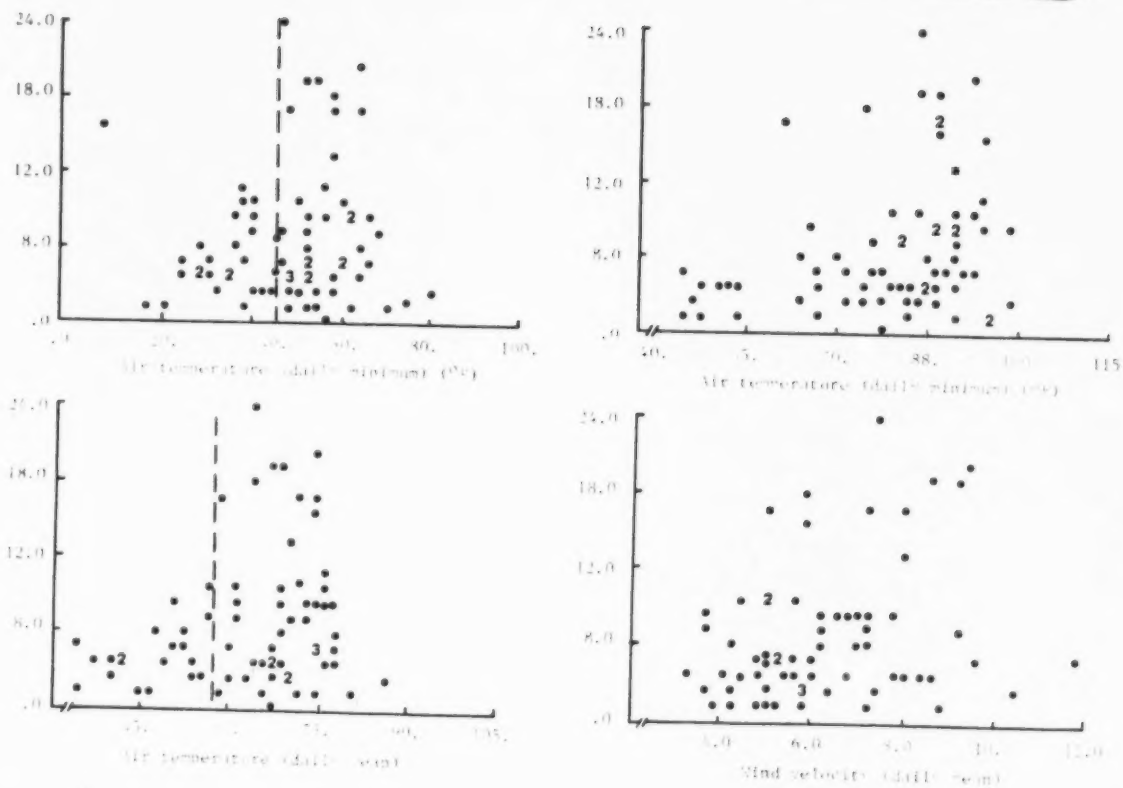


Figure 23. (continued.) Number of *Sorex* captures as a function of weather conditions.

TABLE 9. CORRELATION ANALYSES

Weather factors	1	2	3	4	5	6	7	8	9	10
1 Precipitation (Daily total)	0.55**	1.00								
2 Precipitation (Nocturnal total)	0.53**	0.78**	1.00							
3 % Cloud cover (Diurnal mean)	0.32**	0.45**	0.29*	1.00						
4 % Cloud cover (Nocturnal mean)	0.40**	0.45**	0.44**	0.74**	1.00					
5 Dew point	0.41**	0.25*	0.24	0.12	0.21	1.00				
6 Relative humidity	0.21	0.44**	0.16	0.53**	0.25*	0.18	1.00			
7 Air temperature (Daily mean)	0.25*	0.04	0.19	-0.15	0.02	0.90**	-0.48**	1.00		
8 Air temperature (Daily maximum)	0.29*	-0.01	0.21	-0.27*	-0.10	0.83**	-0.50**	0.94**	1.00	
9 Air temperature (Daily minimum)	0.14	0.03	0.03	-0.01	0.07	0.78**	-0.36**	0.83**	0.71**	1.00
10 Wind velocity (Daily mean)	0.21	0.24	0.14	0.27*	0.29*	-0.15	0.19	-0.22	-0.14	1.00

**p < 0.01.

*p < 0.05.

of variance and correlation analysis and can involve a combination of interval and nominal scales. Analyses were made for rainy and non-rainy conditions; other factors were treated as continuous data. This analysis examined the combinations of predictor variables (i.e., weather conditions) which produce the minimum unexplained residual variance in the dependent variable (i.e. *Sorex* captures). the best fit ANCOVA model includes four predictor variables, namely, cloud cover, dew point, mean air temperature, and minimum air temperature, each adding significantly to the model (Table 10). The coefficient of determination (adjusted R-squared) was 0.47; indicating that these four variables accounted for 47% of the variation in trap captures.

Other Small Animals--An $(x + 0.05)$ transformation was used to normalize all data. The ANCOVA was used to develop a model using weather conditions as predictor variables and total amphibian captures as the dependent variable. The best-fit model (adjusted R-squared = 0.17) contains three predictor variables, namely, dew point, mean air temperature and total precipitation, each adding significantly to the model (Table 11). This indicates that 17% of the observed variation in amphibian captures can be explained by these three weather variables.

The temporal patterns of six animal types (three species, two genera and one order) were examined. These groups were formed to obtain sufficient numbers for statistical analysis. Table 12 presents correlation coefficients for total captures of the 6 animal groups and 10 weather factors. Precipitation and cloud cover are positively associated with the capture of the vole (*Microtus*), leopard frog (*Rana pipiens*), green frog (*R. clamitans*) and American toad (*Bufo americanus*). The trap captures of snakes are not correlated with any of the calculated weather factors.

Another correlation analysis was performed to determine if weather conditions were associated with which side of the drift fence the animals were captured. In this analysis only data from drift fences located parallel to habitat boundaries were included. Two values, namely, (W-D) and (W-D)/(W+D) were calculated. Correlation coefficients for these values and the 10 weather parameters are included in Table 13. Only *B. americanus* shows consistent correlation with the calculated values. Precipitation, cloud cover, air temperature and humidity are correlated with fence site.

DISCUSSION

General Comments

Baseline studies of small animal populations often are concerned with species presence and abundance, the seasonal use of different habitats (including migration routes), and the presence of rare or endangered species. Drift fence trapping is useful in providing some of this information.

TABLE 10. ANALYSIS OF COVARIANCE TABLE FOR SOREX CAPTURES ALL TERMS
REORDERED LAST

Source of variation	d.f.	Sums of squares	Mean squares	F-ratio
Cloud cover (Nocturnal total)	1	263.3	263.3	16.6**
Dew point	1	76.5	76.5	4.8*
Air temperature (Daily mean)	1	163.9	163.9	10.3**
Air temperature (Daily minimum)	1	256.8	256.8	16.2**

** = ($p < 0.05$)

* = ($p < 0.05$)

TABLE 11. ANALYSIS OF COVARIANCE TABLE FOR AMPHIBIAN CAPTURES ALL TERMS
REORDERED LAST

Source of variation	d.f.	Sums of square	Mean squares	F-ratio
Dew point	1	7.05	7.05	11.25**
Air temperature (Daily mean)	1	3.30	3.30	5.27*
Precipitation (Daily total)	1	3.34	3.34	5.33*

** = ($p < 0.01$)

* = ($p < 0.05$)

TABLE 12. PRODUCT-MOMENT CORRELATION COEFFICIENTS FOR 10 WEATHER FACTORS AND SIX ANIMAL GROUPS.
LEVELS OF SIGNIFICANCE FOR $p < 0.05$ (*) AND $p < 0.01$ (**) ARE GIVEN

Weather factor		<i>Microtus</i>	<i>R. pipiens</i>	<i>R. clamitans</i>	<i>B. americanus</i>	Snakes
1	Precipitation (Daily total)	0.50**	0.26*	0.24*	0.42**	-0.15
2	Precipitation (Nocturnal total)	0.55**	0.25*	0.05	0.52**	-0.13
3	% Cloud cover (Diurnal mean)	0.23	0.24*	0.23	0.24*	-0.00
4	% Cloud cover (Nocturnal mean)	0.40**	0.32**	0.32*	0.33**	-0.11
5	Dew point	0.16	0.09	0.18	0.06	-0.18
6	Relative humidity	-0.01	0.07	0.15	0.20	0.08
7	Air temperature (Daily mean)	0.12	-0.01	0.06	-0.01	-0.17
8	Air temperature (Daily maximum)	0.11	-0.02	0.02	-0.00	-0.08
9	Air temperature (Daily minimum)	0.04	-0.01	0.07	-0.02	-0.19
10	Wind velocity (Daily mean)	0.32**	0.14	0.16	0.14	0.01

Table 13. PRODUCT-MOMENT CORRELATION BASED ON VALUES CALCULATED FROM THE SIDE OF THE FENCE ON WHICH THE ANIMALS WERE CAPTURED AND 10 WEATHER PARAMETERS

Weather factor	Sorex		Microtus		R. pipiens		R. melanota		B. americana		Snakes	
	a	b	a	b	a	b	a	b	a	b	a	b
1 Precipitation (Daily total)	-0.01	-0.01	-0.28*	-0.14	-0.06	-0.23	0.05	-0.02	-0.35**	-0.15	0.06	0.06
2 Precipitation (Nocturnal total)	0.02	-0.03	-0.31**	-0.17	-0.02	-0.18	-0.01	-0.11	-0.42**	-0.07	0.09	0.14
3 % Cloud cover (Diurnal mean)	-0.07	0.03	-0.13	-0.07	0.09	-0.10	-0.06	-0.08	-0.31**	-0.33**	-0.13	-0.08
4 % Cloud cover (Nocturnal mean)	0.04	0.12	-0.09	0.04	0.11	0.06	-0.19	-0.15	-0.40**	-0.32**	-0.04	-0.10
5 Dew point	-0.24*	-0.04	-0.05	0.04	0.02	0.13	-0.07	-0.02	0.14	0.20	0.15	0.20
6 Relative humidity	-0.09	-0.08	-0.17	-0.18	-0.07	-0.11	-0.21	-0.10	-0.27*	-0.27*	-0.08	-0.12
7 Air temperature (Daily mean)	-0.17	0.00	0.02	0.12	0.03	0.16	0.00	0.02	0.19	0.29*	0.20	0.25*
8 Air temperature (Daily maximum)	-0.16	0.00	-0.04	0.06	0.08	0.22	-0.09	0.01	0.21	0.33**	0.16	0.20
9 Air temperature (Daily minimum)	-0.18	0.05	-0.13	0.00	-0.03	0.06	-0.03	0.00	-0.17	0.29*	0.16	0.09
10 Wind velocity (Daily mean)	0.10	0.03	0.20	-0.18	0.02	-0.02	-0.19	-0.22	0.27*	0.22	-0.04	-0.07

a is (W-D) and b is (W-D)/(W+D).

* $p \leq 0.01$.

** $p \leq 0.05$.

Drift fence-pitfall trapping proved to be a suitable method for capturing a variety of small animals. Casual field observation confirmed the importance of the drift fence in bringing animals to traps. Numerous animals, including small mammals, turtles, snakes, frogs, toads, and salamanders were observed moving to a drift fence and subsequently traveling along the fence and falling into pit traps. This trapping method may not be as effective for animals that use runways (e.g. some small mammals) or snakes that travel on scent trails. The drift fence material may affect animal captures. For example, a few amphibians were found climbing over fences made of aluminum screening.

Trap Size and Shape

A variety of trap sizes and shapes are necessary to capture different animal types. The size and body form of animals dictate what trap shape will be successful. For example, since large frogs are able to jump out of a shallow can or a deep can with a large opening, they are best captured in pitfall traps. The surface diameter of the trap limits the size of turtle that can be captured: occasionally turtles were found wedged into the traps. The larger snakes captured in this study were usually found in large, deep traps, probably because these snakes can span the distance over smaller traps. Trap depth limits the length of snake that can escape. Some frogs (i.e. the *Hylidae*) and very young snakes are able to escape from pitfall traps by clinging to the sides. The short-tailed shrew (*Blarina brevicauda*) was captured most frequently in narrow, shallow traps.

Orientation

The orientation of drift fences also affects the kind of animals captured. For example, amphibians were caught more frequently on fences running parallel to land-water boundaries and mammals were captured more frequently on fences running perpendicular to land-water boundaries. This difference is probably due to species habitat requirements. Small mammals tend to travel parallel to water boundaries while amphibians often emerge or enter water (i.e., travel perpendicular to water boundaries). Proper orientation of fences can increase the likelihood of capturing rare species. In this study in all locations more mammals species were captured on "perpendicular" fences and more amphibian species were captured on "parallel" fences.

Drift fence orientation is useful in monitoring migration patterns. During migratory periods, one side of a fence can exhibit many more captures than the other. If two fences are located at right angles to each other, data from both fences will provide detailed information on migration direction (Figure 24). This configuration was particularly useful with Ranid frogs and salamanders.

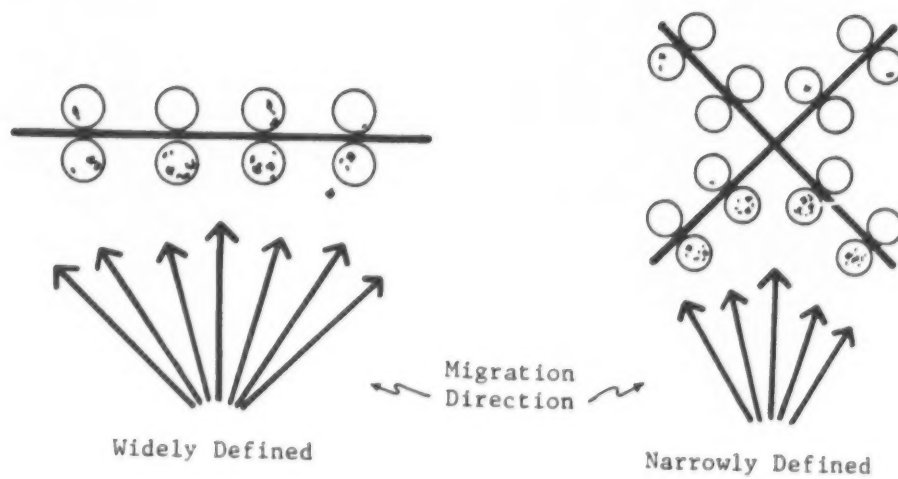


Figure 24. Drift fence orientation illustrating migration direction determination.

Side differences in drift fence captures also may be useful in measuring habitat degradation. A change in captures on one side of a fence may result from habitat changes. In this study, some animals on some fences showed different (W-D) capture patterns with time. This pattern cannot be interpreted since evidence of habitat degradation resulting from power plant operation is not at hand and because animals normally exploit changing habitats seasonally.

Timing

The temporal patterns of animal captures are quite complex. For example, trap capture data indicate dissimilar activity periods for the two species of Ranid frogs *R. pipiens* and *R. clamitans* (Figure 25). The non-random nature of trap captures suggests that it is not possible to trap for a short period of time and accurately describe animal assemblages. The shorter the census duration, the greater the possibility of error.

Seasonal differences in movement were recorded for all animals. Typically, most frogs were captured during the early spring and fall migrations. Salamanders were captured in even more discrete periods of time (i.e., a few days). Small mammals tend to be most active during summer. Some mammals (e.g. *Microtus*) remain quite active during the winter. Others, like deer mice (*Peromyscus*), were captured sporadically during the mating period and the time of dispersal of the young. Turtles are most active during the early summer. Snakes also are active during this time but remain so until the early fall.

Trapping efforts were facilitated if certain times (e.g., seasons or weather conditions) could be determined when all or most small animals are active. In this study, diversity (Simpson 1949) in trap captures changed radically from day to day but no pattern is evident.

Recommendations for future baseline investigations are to collect a full year of data. This period allows a basic understanding of local small animal populations (e.g., presence and abundance, seasonal changes, rare species, etc.). Frequent, regular emptying of pitfall traps is essential to the success of the method and daily visits in the early morning probably are best. Reptiles can withstand longer periods in traps, but amphibians in dry, hot weather and some mammals, particularly the insectivores cannot. If daily inspection of traps for a full year is too expensive, traps can be opened and closed (i.e., tightly covered) at regular intervals, perhaps weekly. This compromise insures sampling of animal populations without undue mortality.

Weather Conditions

Weather analyses indicate that two types of weather parameters, moisture variables and temperature variables, are important in controlling small

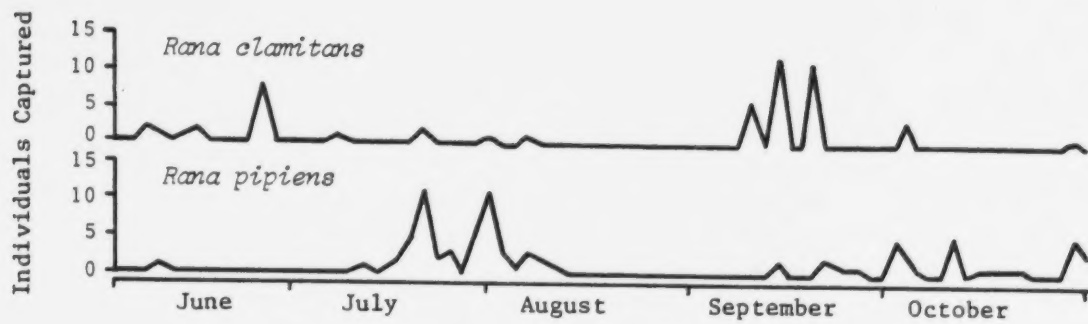


Figure 25. A comparison of individuals captured for *Rana clamitans* and *R. pipiens*.

animal movements and significant interactions exist between temperature and moisture. These results are similar to those reported for *Sorex* (Doucet and Bider 1974) and other small animals (Bider 1968, Marten 1973).

For *Sorex*, precipitation seems to be the most important single factor affecting trap captures. However, in the ANCOVA model where several variables are considered, the combination of cloud cover, dew point and temperature is a better predictor of *Sorex* captures than precipitation alone or any combination of variables with precipitation. These findings concur with Bider's (1968), that the effect of weather on animal activity stems from several interacting factors.

These findings suggest that an integrated measure of weather conditions might be useful in predicting animal numbers. Barometric pressure (i.e., rising, falling, high and low) is an indicator of regional weather systems. Low barometric pressure is generally associated with cloudy, warm, humid conditions. Although it is possible that barometric pressure could function as a triggering mechanism for activity in some animals, this idea is not supported by correlation and regression analyses.

CONCLUSIONS

Considerable information necessary in baseline studies can be collected on small animal populations with drift fence-pitfall traps--including species presence, estimate of abundance, habitat use, seasonal changes, and general migration patterns. The trapping results of the study were affected by trap dimensions, drift fence orientation, time and weather conditions. Of these, weather cannot be controlled. The influence of weather on animal movement (i.e., trap capture) was quantified and appears to be considerable. This effect on trapping results could be accounted for in future studies by a reliable predictive model that would yield true population estimates given actual numbers captured during specific weather conditions.

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APPENDIX A. BIRD SPECIES LIST

Family	Species	Years sighted				
		1972	1973	1974	1975	1976
<i>Coliidae:</i>						
Loons	Common loon			X	X	X
<i>Podicipedidae:</i>						
Grebes	Pied-billed grebe	X	X	X	X	X
	Horned grebe				X	X
<i>Phalacrocoracidae:</i>						
Cormorants	Double-crested cormorant				X	
<i>Anatidae:</i>						
Swans, geese, and ducks	Whistling swan	X		X		X
	Canada goose	X	X	X	X	X
	Snow goose			X	X	
	Canvasback			X	X	
	Redhead		X		X	X
	Scaup	X	X		X	X
	American golden-eye		X	X	X	X
	Mallard	X	X	X	X	X
	Pintail		X			
	Baldpate		X		X	X
	Northern shoveller		X	X	X	X
	Blue-winged teal	X	X	X	X	X
	Green-winged teal	X	X	X		X
	Wood duck	X	X	X	X	X
	Bufflehead	X	X	X	X	X
	Hooded merganser			X	X	
	Red-breasted merganser		X		X	X
	American merganser		X	X	X	X
	Ruddy duck				X	X
	Ring-necked duck				X	X
	Gadwall					X
<i>Cathartidae:</i>						
American vultures	Turkey vulture		X			
<i>Accipitridae:</i>						
Hawks, old world vultures and harriers	Red-tailed hawk	X	X	X	X	X
	Red-shouldered hawk	X	X	X		
	Broad-winged hawk	X	X	X	X	
	Rough-legged hawk				X	X
	Harrier	X	X	X	X	X
	Kestrel	X	X	X	X	
	Cooper's hawk		X		X	
	Sharp-shinned hawk		X			
	Bald eagle			X		
	Osprey	X	X	X		X

APPENDIX A: (Continued)

Family	Species	Years sighted				
		1972	1973	1974	1975	1976
<i>Tetraonidae:</i>						
Grouse and ptarmigan	Ruffed grouse	X	X	X	X	X
<i>Phasianidae:</i>						
Quail, pheasant, and peacock	Ring-necked pheasant	X	X	X	X	X
	Bob-white quail		X			
<i>Ardeidae:</i>						
Heron and bitterns	Great blue heron	X	X	X	X	X
	Green heron	X	X	X	X	X
	Black-crowned night heron				X	X
	Yellow-crowned night heron	X				
	Great egret		X	X	X	X
	American bittern	X	X	X	X	X
	Least bittern			X	X	X
<i>Gruidae:</i>						
Cranes	Sandhill crane	X	X	X	X	X
<i>Rallidae:</i>						
Rails, gallinules and coots	Virginia rail	X	X	X	X	X
	Sora rail	X	X	X	X	X
	Coot	X	X	X	X	X
<i>Charadriidae:</i>						
Plovers, turnstones and surfbirds	Killdeer	X	X	X	X	X
	Golden plover				X	
<i>Sclopacidae:</i>						
Woodcock, snipe and sandpipers	Woodcock	X	X	X	X	
	Common snipe	X	X	X	X	X
	Spotted sandpiper	X	X	X	X	
	Solitary sandpiper	X	X	X	X	X
	Semipalmated sandpiper		X			
	Least sandpiper	X			X	
	Baird's sandpiper				X	
	Pectoral sandpiper			X		
	Sanderling		X			
	Dowitcher	X				
	Greater yellowlegs			X		X
	Lesser yellowlegs	X		X		X
	Dunlin					X

APPENDIX A. (Continued)

Family	Species	Years sighted				
		1972	1973	1974	1975	1976
<i>Laridae:</i>	Bonaparte's gull		X	X		
Gulls and	Herring gull		X	X	X	
terns	Ring-billed gull		X			
	Black tern	X	X	X	X	
<i>Columbidae:</i>	Rock dove		X	X	X	X
Pigeons and	Mourning dove	X	X	X	X	X
doves						
<i>Cuculiformes:</i>	Yellow-billed cuckoo		X	X	X	X
Cuckoos, road-	Black-billed cuckoo	X	X	X	X	X
runners and anis						
<i>Strigidae:</i>	Great horned owl		X	X		
Owls	Barred owl	X	X	X	X	X
<i>Caprimulgidae:</i>	Common nighthawk	X			X	X
Goatsuckers						
<i>Apodidae:</i>	Chimney swift		X	X	X	
Swifts						
<i>Trochilidae:</i>	Ruby-throated hummingbird	X	X	X	X	
Hummingbirds						
<i>Alcedinidae:</i>	Belted kingfisher	X	X	X	X	X
Kingfishers						
<i>Picidae:</i>	Pileated woodpecker	X	X	X	X	X
Woodpeckers	Red-bellied woodpecker	X	X	X	X	X
	Red-headed woodpecker	X	X	X	X	X
	Hairy woodpecker	X	X	X	X	X
	Downy woodpecker	X	X	X	X	X
	Common flicker	X	X	X	X	X
	Yellow-bellied sapsucker	X	X	X	X	X
<i>Tyrannidae:</i>	Eastern kingbird	X	X		X	X
Flycatchers	Crested flycatcher	X	X	X	X	X
	Alder flycatcher	X	X	X	X	X
	Least flycatcher			X	X	X
	Acadian flycatcher		X			
	Yellow-bellied flycatcher		X			
	Eastern phoebe	X	X	X	X	X
	Eastern wood pewee	X	X	X	X	X

APPENDIX A. (Continued)

Family	Species	Years sighted				
		1972	1973	1974	1975	1976
<i>Alaudidae:</i>						
Larks	Horned lark			X	X	
<i>Hirundinidae:</i>						
Swallows	Tree swallow					
	Bank swallow	X	X	X	X	X
	Barn swallow	X	X			
	Cliff swallow	X	X	X	X	X
	Rough-winged swallow		X	X		X
	Purple martin	X	X	X	X	X
			X	X		
<i>Corvidae:</i>						
Crows, jays, and magpies	Blue jay	X	X	X	X	X
	Crow	X	X	X	X	X
<i>Paridae:</i>						
Titmice, verdins and bushtits	Tufted titmouse					
	Black-capped chickadee				X	
		X	X	X	X	X
<i>Sittidae:</i>						
Nuthatches	White-breasted nuthatch	X	X	X	X	X
<i>Certhiidae:</i>						
Creepers	Brown creeper		X	X	X	X
<i>Troglodytidae:</i>						
Wrens	House wren					
	Winter wren	X	X	X	X	X
	Long-billed marsh wren		X		X	
	Short-billed marsh wren	X	X	X	X	X
		X	X	X	X	X
<i>Mimidae:</i>						
Mockingbirds and thrashers	Grey catbird	X	X	X	X	X
	Brown thrasher	X	X	X	X	X
<i>Turdidae:</i>						
Thrushes, solitaires and bluebirds	American robin	X	X	X	X	X
	Wood thrush	X	X	X		X
	Swainson's thrush	X	X			X
	Hermit thrush	X	X			X
	Gray-cheeked thrush	X	X	X	X	
	Veery	X	X	X	X	
	Eastern bluebird	X	X	X	X	X
		X		X		

Family	Species	Years sighted				
		1972	1973	1974	1975	1976
<i>Sylviidae:</i>						
Gnatcatchers and kinglets	Blue-gray gnatcatcher	X	X	X		X
	Golden-crowned kinglet	X	X	X	X	X
	Ruby-crowned kinglet	X	X	X	X	X
<i>Motacillidae:</i>						
Wagtails and pipits	American pipit			X	X	
<i>Bombycillidae:</i>						
Waxwings	Cedar waxwing	X	X	X	X	X
<i>Laniidae:</i>						
Shrikes	Northern shrike		X	X	X	X
	Loggerhead shrike	X	X			
<i>Sturnidae:</i>						
Starlings	Starling	X	X	X	X	X
<i>Vireonidae:</i>						
Vireos	Red-eyed vireo	X	X	X	X	X
	Yellow-throated vireo	X		X	X	X
	Warbling vireo		X	X	X	X
	Philadelphia vireo				X	
	Blue-headed vireo				X	
<i>Parulidae:</i>						
Wood warblers	Black and white warbler	X	X	X	X	X
	Prothonotary warbler	X	X		X	X
	Blue-winged warbler	X	X			
	Golden-winged warbler			X	X	
	Tennessee warbler	X		X	X	X
	Nashville warbler	X	X	X	X	
	Parula warbler				X	
	Yellow warbler	X	X	X	X	X
	Magnolia warbler	X	X	X	X	X
	Black-throated blue warbler				X	
	Black-throated green warbler	X		X	X	X
	Yellow-rumped warbler	X	X	X	X	X
	Cerulean warbler		X	X		X
	Blackburnian warbler	X	X		X	
	Chestnut-sided warbler	X	X	X	X	X
	Bay-breasted warbler	X	X	X	X	
	Blackpoll warbler	X	X		X	
	Palm warbler	X	X		X	X

APPENDIX A: (Continued)

Family	Species	Years sighted				
		1972	1973	1974	1975	1976
<i>Parulidae:</i>						
Wood warblers	Ovenbird	X	X	X		
	Northern waterthrush	X	X	X	X	
	Kentucky warbler				X	
	Connecticut warbler	X			X	
	Mourning warbler		X	X		
	Common yellowthroat	X	X	X	X	X
	Yellow-breasted chat				X	
	Wilson's warbler	X	X	X	X	
	Canada warbler			X		
American redstart	X	X	X	X	X	
<i>Floceidae:</i>						
Weaver finches	House sparrow	X	X	X	X	X
<i>Icteridae:</i>						
Meadowlarks, blackbirds and orioles	Meadowlark	X	X	X	X	X
	Red-winged blackbird	X	X	X	X	X
	Rusty blackbird	X	X	X		X
	Brewer's blackbird			X	X	X
	Brown-headed cowbird	X	X	X	X	X
	Purple grackle	X	X	X	X	X
	Yellow-headed blackbird	X		X		
	Northern oriole	X	X	X	X	X
	Bobolink			X	X	
<i>Thraupidae:</i>						
Tanagers	Scarlet tanager	X	X	X	X	X
<i>Pringillidae:</i>						
Grosbeaks, finches, sparrows and buntings	Rose-breasted grosbeak	X	X	X	X	X
	Evening grosbeak	X	X			
	Pine grosbeak	X				
	Cardinal	X	X	X	X	X
	American goldfinch	X	X	X	X	X
	Eastern towhee	X	X	X	X	X
	Tree sparrow	X	X	X	X	X
	Song sparrow	X	X	X	X	X
	Field sparrow	X	X	X	X	X
	Swamp sparrow	X	X	X	X	X
	Vesper sparrow	X	X	X	X	X
	Savannah sparrow		X			X
	Chipping sparrow	X	X	X		X
	White-crowned sparrow	X	X	X		X
	White-throated sparrow		X	X	X	X

APPENDIX A: (Continued)

Family	Species	Years sighted				
		1972	1973	1974	1975	1976
<i>Eringillidae:</i>						
Grosbeaks, finches, sparrows and buntings	Fox sparrow	X	X	X	X	X
	Grasshopper sparrow				X	
	Dickcissel				X	
	Dark-eyed junco	X	X	X	X	X
	Red poll	X		X	X	
	Red crossbill	X				
	Indigo bunting	X	X	X	X	X
	Snow bunting			X	X	
	Purple finch					X
	Sharp-tailed sparrow					X

APPENDIX B. PRACTICAL GUIDE TO DRIFT FENCE-PITFALL TRAPPING

1. METHOD. A drift fence is used to channel small animals into containers set into the ground. Field observations indicate that animals that approach the fence tend to travel along it and subsequently fall into pitfall traps. Trap dimensions dictate the kind and size of animal that can escape.
2. MATERIALS. Fences and traps can be obtained inexpensively. Fences must be sturdy enough to resist disturbance (e.g., aluminum sheeting) and high enough to prevent small animals from crossing over them. Traps can be fabricated from used containers of various dimensions (i.e., depth, size and shape of opening, etc.).
3. CONSTRUCTION. Fences need to be set in the ground to prevent animals from passing under them. Pitfall traps are buried at ground level touching the side of the fence.
4. LOCATION. Fence locations usually are dictated by the purpose of a study, but some general information is useful. Ecotones support a rich small animal community and can be effectively trapped by using a continuation of drift fences in an "L", "T", or "X" formation.
5. MAINTENANCE. Traps need to be emptied regularly, at least every day as many small animals are sensitive to heat, cold, lack of food, etc. Many animals are captured at night, making the early morning a good time to empty traps. An animal should be removed carefully from the trap (gloves may be required with some small mammals that bite), recorded, and released on the opposite side of the fence. Traps can be covered securely when not in use.
6. RESULTS. Drift fence-pitfall trapping results yield considerable information including species presence, a rough idea of abundance (e.g., with mark-recapture), animal habitat use, season, population changes and general migration patterns.
7. PROBLEMS. Animal mortality in pitfall traps can occur in a variety of ways, e.g., a trapped animal killing another, rainfall either drowning or wetting the fur of mammals; dry hot weather causing desiccation, amphibians; cold nights; lack of food; or large predators (e.g. opossum, raccoon, snakes). This can be minimized by emptying the traps regularly, designing traps to meet specific animal requirements, and closing traps when evidence of large predators has been observed (e.g., footprints).